AI Techniques for supporting human to human communication in CHAOS

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Abstract

Communication among group's members can be problematic being often difficult to interprete ambiguous messages in a correct way . The paper describes the main features of a human to human communication support, called CHAOS, for what concerns the help it provides to its users both in preventing misunderstandings and in allowing message disambiguation. These functionalities are implemented in a specific module (the Group Language Expert module), which makes use of Natural Language Processing techniques. Their application is illustrated together with some possible improvements of the implemented functionalities.

1. Some communication problems within groups

In everyday life people participate in communications going on within different groups: family, friends, colleagues, etc. Independently of the kind of group in question, their experience as actors more or less directly involved in such communication shows two contrasting aspects.

On one hand, the group's members seem to feel very secure since they know how to behave within each group. In fact, the belonging to one group allows them to know whom to contact in order to obtain information, where to look for finding a certain thing, how to speed up the communication in order to receive a quick answer, etc. New people joining a group do not show the same sense of security: they do not ask for information but mainly ask to whom they must turn for the information; they are not able to retrieve things without some help; if they abbreviate the communication they risk being misunderstood, if they are detailed in explaining their needs they risk appearing boring and then put aside.
Indeed, the sense of security in behaving within a group mainly depends on the fact that the common experience gained by its members defines a framework, a set of references (rules or habits, knowledge or conventions) which are shared among them and allow behaviours, utterances, moves to be understood independently of the degree of precision of their contents.

On the other hand, the above sense of security is potentially a major source of communication problems since it induces an abbreviated form of interaction among the group's members. In fact, the common experience and habit let them behave and communicate as if all other members could share the same set of references at any moment, and then understand implicit information and solve the possible ambiguities in any circumstances. Actually, this is not always the case because of the absolute uniqueness of each group member's history.

In order to describe how member's histories contribute both the defining of a common framework and the determination of its possible individual variants, let us outline how groups form and develop during their life. For the scope of the paper let us concentrate on groups which are formed in order to do some cooperative work: i.e., we consider groups of co-workers. At the beginning, the members do not share many common experiences: they know why they are in some way cooperating, they share some part of a professional language, they eventually share common experiences gained within other groups different from the present one, eventually they belong to the same organization/company. When the cooperation starts, they do things and communicate by referring to objects, people, operations, goals, difficulties, etc.; when misunderstandings or incomprehensions arise, they ask for or give clarifications, in this way building the set of references we mentioned before. This process is, however, not uniform: cooperation on some specific topic can involve only part of the group, or require a close interaction with external groups; in addition, some member can leave the group, some new people can join it during the time. Consequently, we can suppose neither that all members share the same set of references (on the contrary, several of them do coexist), nor that these different sets are mutually consistent (on the contrary, each subgroup can have a different perception of the same event, object or person participating to the group's life). For example, if an activity involves only a subgroup, then almost all its member have an updated information about what is to be done, who is in charge of what or who is the project responsible; instead, members of other subgroups can have knowledge about a previous state of the project, which is no longer consistent with the present one. This can give rise to misunderstandings, to unfair or uneffective communication among members of different groups when speaking about the project. On the other hand, a continuous broadcast telling the group members about each change among the group could overwhelm them and produce an even worse result.

To sum up, cooperation tends to make reference sets uniform; individual or subgroup's experience tends to differentiate them. Communication within the group tends to enhance its cohesion, the degree by which its members feel part of it; communication outside the group, which is necessary to the dynamic survaival of the group itself, and communication within subgroups, which is essential to the group's efficacy and efficiency, tend to reduce its cohesion and the degree of collective familiarity.

Each group member has to handle this complex and contradictory situation by exploiting the group's common references in order to reduce the communication/interaction costs and to improve its efficacy, and by compensating the differences between the set of references in order to recover from ambiguous or incomplete information within the communication/interaction he is involved in.
This process requires a timely reconstruction of the framework in which a specific communication can be properly interpreted, i.e., of the set of references appropriate both to the person involved in the communication and to the particular communication point. This situation is typical of any kind of communication, but is especially crucial when the possible set of interlocutors, each with its own set of references, is large, or when the communication is highly asynchronous, that is, is not face to face or distributed in time. Then, recovering the appropriate framework can become a difficult task and a big source of communication ineffectiveness.

For example, let us consider the negotiation of a task to be shared by different persons. At each moment in time every participant can have open communications about the initial proposal, about some counteroffers, about some requests of information and the like, with different interlocutors. In addition, the negotiation can last for weeks before it ends. In this situation it can be difficult for the receiver of a new message (spoken or arrived via e-mail) to recover the appropriate context, i.e., the history of the previous communications and the information more or less implicitly involved in them, which is necessary for a correct interpretation of the message.
In fact, the interpretation process can make use of information about the group, which is not directly referenced within the communication (for example, the message can refer to a project in a certain state or to a person playing a certain role without mentioning them explicitly). So, it may happen that this information is not easily available since the network of active communications and of the commitments they imply, both at the individual and group level, is complex, and the retrieval of the most updated information requires a long and costly process.

The difficult reconstruction of the message context is another potential source of communication problems. In fact, this process either encreases the communication overhead, if the message receiver asks his interlocutor for help, or it generates an endless chain of misunderstandings, if he pretends to have understood but it is not the case.

2. The background and the aims of CHAOS

The above considerations led us to design a software module (called Group Language Expert module, GLE). Its aim is to reduce the effort the communication among cooperating people requires, by allowing them to exchange messages containing incomplete infomation without losing the communication 'robustness'(i.e., by anticipating possible misunderstandings), and by helping them to manage the information and the commitments involved in this communication. It has to be emphasized that the kind of communication we are mainly concerned with is asynchronous (e.g., via an electronic medium) communication aimed at allowing the cooperation among group activities.

GLE is a part of a human to human communication support prototype, called CHAOS (Commitments Handling Active Office System) [4],[5] whose main aims are sketched here below in order to elicit the context in which GLE makes sense. CHAOS provides the user with support in handling:

1) the network of communication he is involved in;
2) the agenda of the committed activities and duties, both at the individual and group level;
3) the organizational links binding the group members one to the other and binding them to the group's activities in terms, respectively of responsibility and experience.

Point 1) concerns the <u>pragmatic dimension</u> [3] of the communication, i.e., the way by which the exchanged words create relations among those who participate in the communication; to this end, we share the same conceptual framework widely discussed in [18].

Points 2) and 3) concern the structuring dimension of the communication, i.e., the way by which the exchanged words mold the structure of the group (at the level both of the agenda and of the organizational setting); to this end, we consider groups as closed and autoreferential social systems [6]. The discussion of this systemic approach is out of the scope of this paper. What is relevant here is that in this view we want to build a communication support system able to 'adapt' to the 'perturbations' provoked by any communication in the group's structure.

The two above-mentioned conceptual frameworks give rise to a main circularity, which is depicted in Fig. 1. A second circularity plugs into the main one, also as shown in Fig.1. This circularity concerns the semantic dimension of the communication, i.e. the way by which the exchanged words assume meanings within the group's structure.

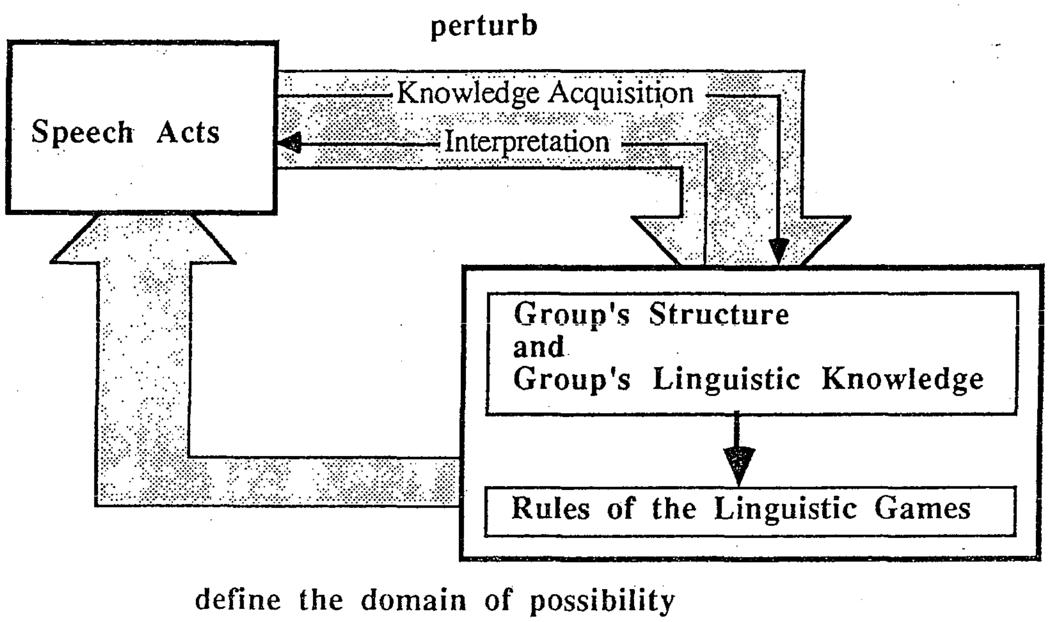

Figure 1: The two circularities implemented in CHAOS.

A fully adaptive system (in the sense explained before) should fully implement the mechanisms underlying the two mentioned circularities. This is, however, impossible since the above mechanisms are by no means fully understood or algorithmic.

This paper concentrates on the semantic dimension of the communication and on the related circularity, and shows to what extent and by means of which features the GLE contributes to make CHAOS a partially adaptive system.

3. The semantic dimension of CHAOS

Two are the foundations supporting the semantic dimension of CHAOS [17]. First of all, the basic circularity between interpretation and knowledge acquisition (semantic circularity); secondly, the existence of a 'consensual domain' (what we intuitively called 'references' in the first section) which allows people mutual understanding and is created by the linguistic interactions of people through the development of a cooperative domain of interactions [13] .

Therefore, if CHAOS aims at supporting its users also in the semantic dimension, (as a basis for the support in the other dimensions, as shown in Fig.1), it must be able to play a role both in the interpretation and knowledge acquisition processes, and in the maintenance of the above consensual domain. Thus it has to deal with the topics typical of the Natural Language Processing and of the Knowledge Representation, i.e., with techniques widely used in Artificial Intelligence applications. The role CHAOS is called to play in the communication among its users characterizes the use and the specialization of such techniques to our needs.
First of all, CHAOS is a communication support, and not an artificial partner in a conversation with its users. Therefore, the need to understand what users communicate to one another is not aimed at constructing some artificial answers (as in Expert Systems or DSS), or to do some action on a more or less artificial reality (as in FMS or in sofisticated Information Systems). On the contrary, CHAOS has to silently listen to who is communicating and to understand what he is speaking about in order to be able to derive the modifications of the interlocutor's consensual domain in regard to the pragmatic and structural dimensions (the network of commitments and the structure of the organization) and the semantic dimension (the group/individual lexicon). This information is basic to the kind of support CHAOS gives to its users, as we shall see in a moment.

SENDER John
ADDRESSEE Paul
ILLOCUTIONARY POINT request
PROPOSITIONAL CONTENT Do you want to implement the system KB, using KEE on the Sun 3/60?
RESPONSE TIME Tomorrow
COMPLETION TIME 31/09/89

Example1: A semi-structured message.

CHAOS allows its users to communicate through a semi-structured interface in which a number of predefined fields are explicitly specified: e.g., who is speaking, which kind of speech act he is using (illocutionary point), who is the addressee of the message, what is its content (propositional content), which is the response deadline. Some fields, typically the ones related to the addressee and to the message content, can be filled by sentences in a natural language. A semi-structured message is shown in Example 1.

In fact, it seems quite unnatural to ask CHAOS's users to exchange either totally formalized messages in which all information used by the system for doing its support activity are inserted in preformatted fields, or to exchange totally free messages whose interpretation immediately becomes unfeasible.

The choice of imposing some kind of structure is based on a number of reflections on how people filter their messages and what kind of information they would like included explicitly in the received messages [15]. For example, if a response deadline is declared in a separate field, the user can perceive more easily the urgency of his response.

In regard to the unstructured part, we are aware of the problem related to natural language interfaces. There is not yet a complete theory of natural language interpretation.So many applications in that area have failed, either because the users expect an application with a natural language interface to exhibit intelligence and are disappointed when it does not, or because an occasional error in a system response can affect the user's overall confidence in the system itself [10]. But we think that the role CHAOS plays in the communication reduces these drawbacks. In the worst case, it is not able to provide a good support both in terms of its performances (computational costs) and in terms of degree of 'adaptiveness'; in any case, it is never asked to simulate a sort of 'intelligent partner'.

The intermediate choice of a semi-structure solves some interpretation problems since some information is inserted in the appropriate field and then is immediately recognizable during the interpretation process. For example, we do not worry about indirect speech acts, for the illocutionary point is one of the information the user must explicitly specify .

The basic functionalities of CHAOS in the semantic dimension are implemented by the GLE and can be summarized as follows:
- to use the information contained in the messages in order to update the various kinds of KBs;
- to signal to the sender if a message could be misunderstood by the addressee;
- to help the receiver to disambiguate the message.

For example, the propositional content of the message shown in Example 1 includes some semantic ambiguities. In fact, the sender chooses to simplify his communication by presupposing that the receiver knows :
- which is the system referred to;
- which is the mentioned SUN 3/60 ;
- the KEE environment and the fact that it is running on a SUN 3/60.

But this cannot be always the case. In fact,
- the receiver could have in "consciousness" several systems having a knowledge base to be implemented, and so he cannot immediately understand what is the one mentioned by his interlocutor;
- the experience related to the KEE environment of the receiver could be too little for enabling him to implement a knowledge base;

- the receiver could not know that KEE is running on a SUN 3/60, since this machine is in a remote office, or has been recently purchased.

The system is able to detect these inconsistencies and, for example:
- advise the sender that the receiver is not an expert of KEE, allowing him to send his message to another addressee fulfilling this skill;
- help the receiver to identify the system referred by the sender;
- help the receiver to find the location of the SUN 3/60.
Furthermore, if the message is understood by the receiver and he state his agreement, the system must record this commitment and the involved entities (i.e. the KB implemented in KEE on the SUN 3/60) in order to be able to exploit this knowledge afterwards.

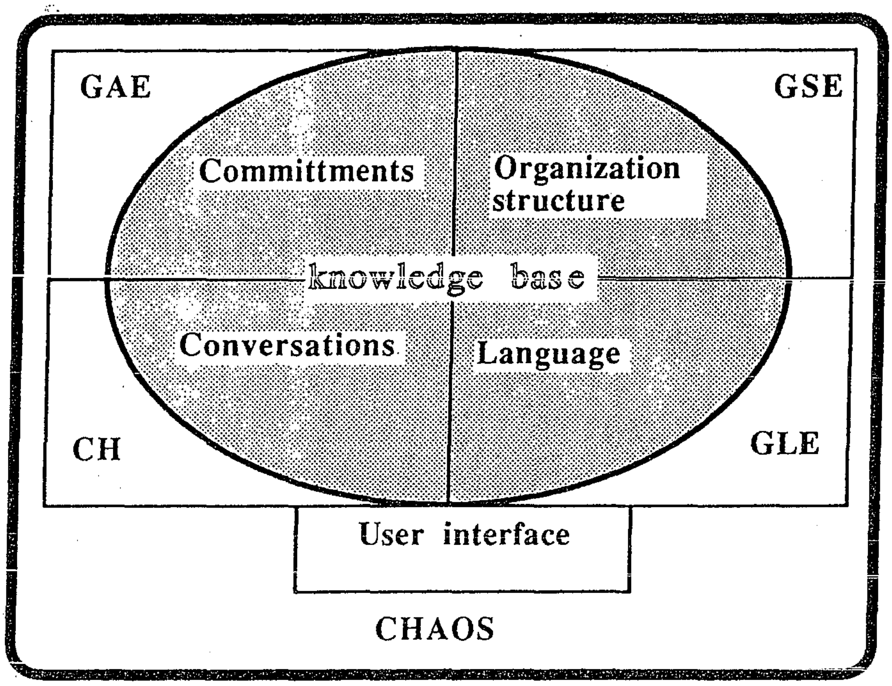

Figure 2: CHAOS structure.

Before entering in more detail about the techniques CHAOS uses to implement these functionalities, it is worthwhile to provide an outline of the system structure (Fig.2). CHAOS is divided into four main modules that have been described in [2], [5]; for our purposes, it is sufficient to note that the CHAOS knowledge base is ideally divided into four parts in accordance with the information they contain:
- the Group Agenda Expert KB contains the current state of the committments taken by some group member;
- the Group Structure Expert KB contains a representation of the group structure in terms of roles and levels of experience of its members;
- the Conversation Handler KB keeps track of the conversations presently open among the group

members;
- the GLE KB contains the entities referred to by people in their conversations. For the purposes of the paper we don't need to enter into the details of this KB structure, even if in what follows we will often refer to it.

4. User Models and Consensual Domains

In the introduction we stressed the fact that group members have individual histories which give rise to different sets of 'references' among them. In order to be adaptive with respect to the evolution of this kind of information, GLE has to be able to represent both the individual knowledge and the knowledge shared among group members, constituting its users different consensual domains.

GLE implements the notion of individual knowledge by means of the concept of user model (UM) which has been developed in the field of Natural Language Processing to represent knowledge about system users. UMs have been used in various contexts, and their definition is not unique. Usually UMs are characterized by the knowledge they include: user goals, plans and attitudes, or user knowledge or belief [12].
Some implemented UMs contain:
- system beliefs on how the user thinks about the domain objects [14];
- system beliefs on the user level of experience [16];
- system beliefs on what the user is trying to do [7].

We are interested in constructing UMs which represent what the system knows about the knowledge and beliefs of its users, relative both to the application domain and to what the other users know about it (meta-knowledge). Modelling the meta-knowledge is basic to the success of the interpretation process. When individuals communicate, the speaker uses a lot of references and anaphoras referring to a knowledge he thinks he shares with the hearer. It is just by making a comparison between what the speaker and the hearer mutually know and the message propositional content that the GLE can detect and solve ambiguities and support the interlocutors in the way we claimed in the previous section.
In this section we describe how GLE organizes both the knowledge and the meta-knowledge of its users, while in the next ones we describe how the UMs evolve to adapt to the linguistic perturbations.

The knowledge on the domain is divided into a general knowledge (prototypes) concerning the abstract structure of the objects and actions and the relations between them, and into a specific knowledge (instances) consisting of the real objects of the domain.
As an example, let us consider the object "module": as a prototype it is a software object (relation IS-A) to be implemented in some programming language, which can be made up of (relation HAS-PART) a number of procedures etc... ; as an instance, it is the module called XX, implemented in Pascal and composed by procedures A, B and C.
GLE assumes that all users share the same general knowledge while it keeps track of what they learn

by conversing about the actual entities of the domain. That implies that each UM contains the user Personal Knowledge about the domain.

In order to take into account users meta-knowledge, GLE defines the notion of Consciously Shared Knowledge (CSK) between pairs of users. Given an entity X, and two users i and j, then X belongs to CSK(i,j) if and only if i knows X; j knows X; i know that j knows X and j knows that i knows X. In other words, the CSK(i,j) represents the meta-knowledge of i about the user j, and viceversa: this meta-knowledge is contained in the UMs of both i and j. This happens for any pair of users.
Given the above definition, we can consider the Personal Knowledge of each user (PK) as the sum of all the knowledge he shares with some other user.

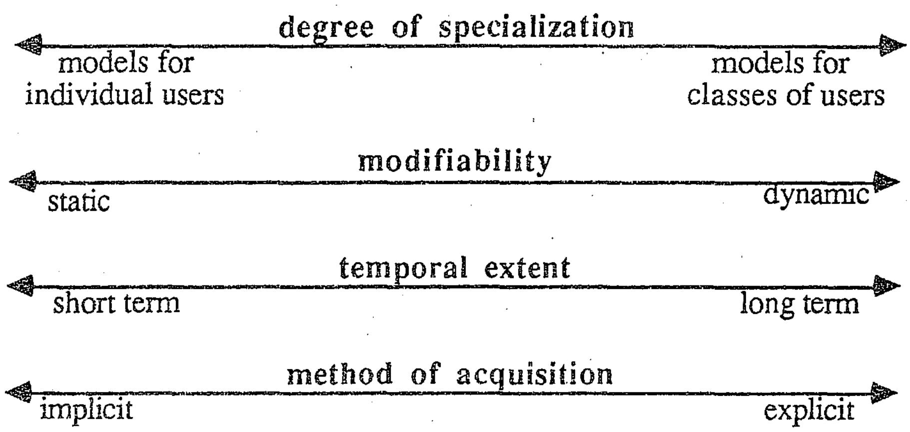

Figure 3: The UM dimensions.

The GLE UMs can be qualified by means of the dimensions proposed in [12] and depicted in Figure 2, as follows:

a) individual: the GLE maintains an individual model of each user ;
b) dynamic: the acquisition mechanism allows each model to incorporate new information as it becomes available during the course of message exchanges (see section 6).
c) long term: UMs are created when new users start using CHAOS, and are maintaned until when the users leave the group. The same dynamic UM is used in all the messages interpretation regarding the related user.
d) implicit: UMs maintenance is performed by the system in an user-transparent way, almost without asking the user about explicit information.

5. The semantic circularity: the interpretation process

As Figure 1 shows, the semantic circularity is based on the interpretation and knowledge acquisition processes: the interpretation uses the same knowledge base that is dynamically brought up to date by

exploiting the information drawn by the interpretation process.
The problem the interpretation process has to face is to establish what entity is denoted by the Verb Phrase and the Noun Phrases[1] within a sentence: this problem is generally called 'reference problem'. One of its special instances is the 'anaphora problem'. According to [11], an anaphora is an abbreviated reference (i.e. "containing fewer bits of disambiguating information") in discourse to some entity in the expectation that the addressee will be able to disabbreviate the reference and thereby determine the identity of the entity.
The most recent works on the semantic ambiguities resolution in Natural Language Processing have indicated that the references cannot be resolved at the sentence level. Rather, the context in which they are inserted must be accounted for. This can be done using the notion of "discourse model" [9].

(1) A->B : " Can you implement the module GSE of CHAOS?"

(2) B->A : " Can I do it in KEE?"

(3) A->B : " In that case you must use the EXPLORER "

(4) B->A: " For resource management problems, I can implement it only beginning from next month "

(5) A->B: " It's too late. Then it's better you test DEMO "

(6) B->A : " OK, first I test its main module"

(7) A->B : "OK"

Example 2: A conversation.

Looking at Example 2, we notice that the conversation consists of two segments concerning two different possible commitments: 1, 2, 3 and 4 concern the implementation of the GSE module of CHAOS, using KEE on a Explorer workstation, while 5 and 6 concern the testing of the main module of another package called DEMO. This segmentation can be modelled using the concept of topic [11]. By 'topic' we mean the main entity that the discourse is about; in CHAOS conversations it represents the committment under discussion at a specific time.
Furthermore, in each sentence of Example 2 many objects and properties are mentioned; they constitute the attentional focus [8] of the conversation. More precisely we can distinguish two types of focus: the explicit focus contains those entities explicitly mentioned in the discourse, while the implicit focus contains those entities that are not explicitly mentioned but are in the interlocutor's consciousness because they are related in some way to the objects in the explicit focus.

[1] The Noun Phrase and Verb Phrase definitions we adopt are the following [1]:
VP:= verb [NP]
NP:=[article] [adjective] noun [PP]
PP:= preposition NP where the '[,]' denotes optionality.

In GLE for each sentence there is a corresponding focus; each focus and each topic are connected to the previous one created during the conversation, producing a focus list and a topic list; furthermore, each focus is related to the corresponding topic.

Figure 4 shows the topic and the focus lists related to the conversation in Example 2. Specifically, the implicit focus related to sentence 5 contains the entities 'Forward-CHAINER' and 'SELECT' related to DEMO by a HAS-PART relation.

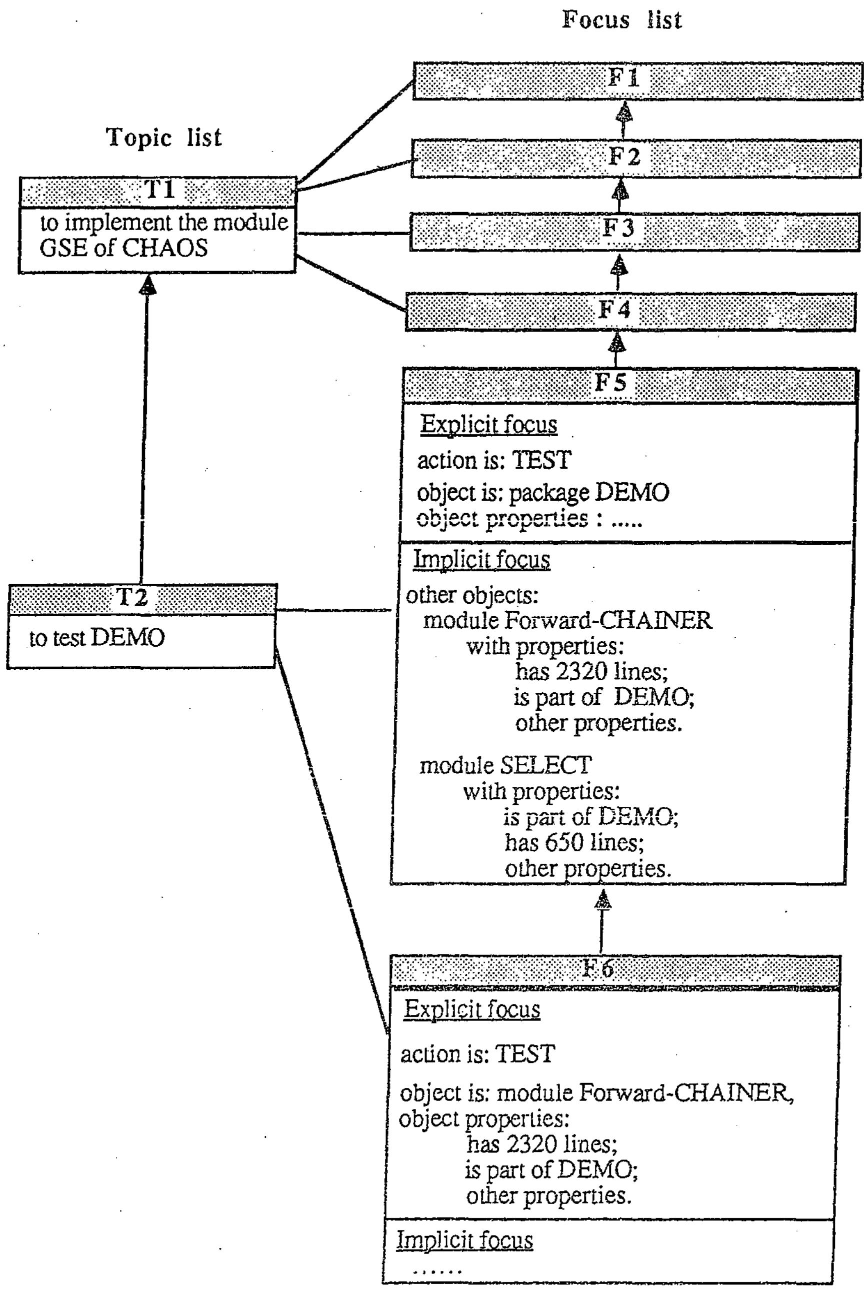

Figure 4: The topic and focus lists.

How can we use these structures in the interpretation process? We have considered both the generic references and the main types of anaphora, i.e. personal pronouns, demonstrative pronouns and ellipsis. For each reference type we have [2] a disambiguation strategy which involves both the focus and topic lists. These strategies use a number of heuristics based on the assumption that the entities in the focus are the most probably referred to in the subsequent utterance; so:

- the personal and demonstative pronouns are likely to refer only to the entities contained in the explicit foci related to the current topic;
- the references including genitive Noun Phrases, possessive adjectives and possessive pronouns involve also the implicit focus. In sentence 6 of Exemple 2, we resolve the reference "its main module" as "Forward-CHAINER", by using the fact that it is contained in the implicit focus related to the previous sentence and that it is the longest module within the implicit focus.

The Noun Phrase references are resolved using the available structures in the following order:

- the system looks for the referent in the focus list ;
- a failure means that the entity is introduced in the conversation for the first time; in this case, the system checks if the entity is in the CSK of the two interlocutors;
- if the system fails, then it looks for the entity in the speaker's PK;
- finally, if also the above search fails, the system looks for the entity within the GLE KB.

For example, if the entity DEMO is introduced in the conversation for the first time, the system checks to see if it is in the CSK of the two interlocutos. If this is not the case, and DEMO is known only by the speaker, the system can lead the hearer in disambiguating it by using the knowledge contained in the speaker's UM. If it's not the case too, some acquisition mechanism must be applyed (see next section).

6. The semantic circularity: the knowledge acquisition process

The knowledge acquisition process is performed by the system in order to bring up to date both the UMs of the interlocutors and the KBs of the GLE, GAE, and GSE, by using the information provided by the interpretation process (Figure5).

In this context the problem the GLE has to face with is to establish when the acquisition process must be activated.

With respect to the GLE KB, not all the new entities mentioned in the conversation have to be immediately inserted in it, because they could be never actually used. So, all the new entities are mantained in the focus list during the conversation, because they can be referenced to in its evolution. Among them, only those on which some committment is actually taken are inserted in the knowledge base; the others expire when the focus list is discarded at the end of the conversation.

In regard to the entities already known by some group member, i.e., already present in the GLE knowledge base, the system must activate the acquisition process in order to update the interlocutor's UMs. In fact, entities whose knowledge is shared among different group members are likely to be referenced to in future conversations.

In this context there is another important problem that the system must face with, i.e., the communication asynchrony. On one hand, if we can assume that the UM of the speaker can be brought up to date exactly when he utters a sentence (because by naming an entity he proves that he knows it), on the other we cannot bring up to date the hearer's UM at the same time. In fact, nothing assures us that the message is immediatly received and read by the hearer, and so an improper updating can negatively influence future interpretation processes. GLE brings up to date the hearer's UM only when he sends back his answer: in doing that, he implicitly proves that he has read the message and that he knows the entities mentioned in it.

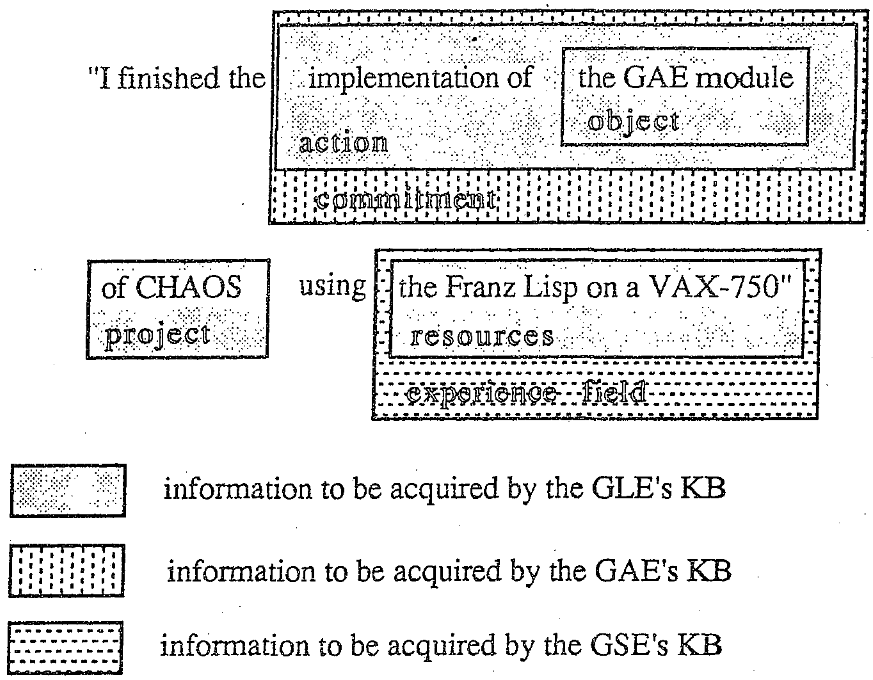

Figure 5 : The acquisition process.

In regard to the KBs of GAE and GSE, the acquisition mechanisms apply when the pragmatic meaning of the message induces some modification of the committment network or of the group organization. In Figure 5, the acquisition process involves the GAE and GSE KBs, because it is a declaration that the job has been accomplished: this modifies both the agenda and the degree of experience of the declarer.

7. CHAOS in the semantic domain: future trends

Let us come back to some points we mentioned in the provious sections.
First of all, it should be clear now to what extent CHAOS is an adaptive system, at least in regard the group's linguistic domain and the knowledge the interpretation process is able to provide to the acquisition process in order to update the GAE ans GSE KBs. In this respect, we have to stress that GLE imposes some constraints on the users: even if we claim that the unstructured part of the message can be in natural language, in any case this language has to have some restrictions.[2] The

[2] The present implementation is quite restrictive in this sense. It is not difficult to imagine how to relax some syntactic constraints in order to enrich the sentences structure [1].

user has to carefully consider the trade-off between constraints and revenues.
As in many other systems, e.g., COORDINATOR, CHAOS messages contain a field called 'comment' which the user can fill with the information he does not want to have in the preformatted fields. In the extreme, he could fill only the comment and the addressee fields: in this case, the system will be not adaptive at all, and will behave as a traditional e-mail system. The other extreme could be that the user pretends the system is able to understand highly elliptical and ambiguous sentences. The system will try to do its best, eventually asking the user for help: if he does not want to become explicit, the system gives up and, again, will behave as an e-mail system.

On the contrary, if we suppose that the user accepts some constraints in order to have some revenues, system functionalities can evolve in a way to provide an encreasingly more helpful support to its users. In fact, the amount of knowledge the system maintains and processes in order to understand the message contents and to update the various KBs is an enormous source of information that can be given back to the users when necessary or requested. Let us explain this point through a couple of examples.
In section 1 we described the difficulties a group member encounters when he has to reconstruct the semantic and pragmatic environment in which a message can be correctly understood. To help this reconstruction, some systems keep track of te sequence of messages (history) the interlocutors have exchanged. The knowledge contained in the topic and focus lists associated to a conversation can improve this support. In fact, on one hand, the last message can be totally meaningless (e.g, in the case it is highly elliptical); on the other hand, all the history could be too long and difficult to read. Few messages enriched by the related topics and foci could be much more understandable and useful.

Another possible evolution concerns the framework of the conversations for information the user can open with the system to ask for information about the organization structure, the functions related to some role, the activities already accomplished or under development, or about objects and resources necessary to them. It would be very nice if the system could give answers tailored to the user level of knowledge, without giving him redundant information. In order to obtain this, CHAOS can use the UMs. In fact, since GLE has made available the UM of the requirer, CHAOS can give back to him the answer concerning the aspects which have chaged e.g., since the last query, without overwhelming him with the infomation he already knows. Or alternatively, it can present him this latter in a different shape.

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