IR-NLI : AN EXPERT NATURAL LANGUAGE INTERFACE TO ONLINE DATA BASES

Giovanni Guida[(o)], Carlo Tasso[(*)]
Istituto di Matematica, Informatica e Sistemistica
Università di Udine
Via Antonini,8 - 33100 Udine, Italy

ABSTRACT

Constructing natural language interfaces to computer systems often requires achievment of advanced reasoning and expert capabilities in addition to basic natural language understanding. In this paper the above issues are faced in the frame of an actual application concerning the design of a natural language interface for the access to online information retrieval systems. After a short discus - sion of the peculiarities of this application, which requires both natural language understanding and reasoning capabilities, the general architecture and fundamental design criteria of a system presently being developed at the University of Udine are then presented. The system, named IR-NLI, is aimed at allowing non-technical users to directly access through natural language the services offered by online data bases. Attention is later focused on the basic functions of IR-NLI, namely, understanding and dialogue, strategy generation, and reasoning. Knowledge represenetation methods and algorithms adopted are also illustarted. A short example of interaction with IR-NLI is presented. Perspectives and directions for future research are also discussed.

I   INTRODUCTION

Natural language processing has developed in the last years in several directions that often go far beyond the original goal of mapping natural language expressions into formal internal representa - tions. Problems concerned with discourse modeling, reasoning about beliefs, knowledge and wants of speaker and hearer, explicitly dealing with goals, plans, and speech acts are only a few of the topics of current interest in the field. This paper is con- cerned with one aspect of natural language processing that we name here reasoning. It is intended as a ba- sic activity in natural language comprehension that

is aimed at capturing speaker's goals and inten - tions that often lie behind the mere literal mea- ning of the utterance. In this work we explore the main implications of reasoning in the frame of an actual application which is concerned with the na- tural language acces to online information retrie- val services (Politt,1981; Waterman,1978).

In particular, we shall present the detailed design of a system, named IR-NLI (Information Re- trieval Natural Language Interface), that is being developed at the University of Udine and we shall discuss its main original features. The topic of natural language reasoning is first shortly illu- strated from a conceptual point of view and compa- red to related proposals. The main features of the chosen application domain are then described and the specifications of IR-NLI are stated. We later turn to the architecture of the system and we go further into a detailed account of the structure of its knowledge bases and of its mode of operation. Particular attention id devoted to the three funda- mental modules STARTEGY GENERATOR, REASONING, and UNDERSATNDING AND DIALOGUE. A sample search session with IR-NLI concludes the illustarion of the pro- ject. A critical evaluation of the work is then pre- sented, and main lines of the future development of the project are outlined with particular attention to original research issues.

II   NATURAL LANGUAGE UNDERSTANDING AND REASONING

Research in natural langage processing has be- come in the last years a highly multidisciplinary topic, in which artificial intelligence, computatio- nal linguistic, cognitive science, psychology, and logic share a wide set of common intrests. In this frame, reasoning is not a new issue. The meaning that we attach to this term in the context of this

work is, nevertheless original. We distinguish in
the natural language comprehension activity between
a surface comprehension that only aims at represen-
ting the literal content of a natural language ex -
pression into a formal internal representation, and
a deep comprehension that moves beyond surface mea-
ning to capture the goals and intentions which lie
behind the utterance (Grosz,1979; Hobbs,1979; Allen,
Perrault,1980). The process that brings from surfa-
ce to deep comprehension is just what we name here
reasoning activity. Differntly from Winograd (1980),
reasoning is not , in our model, something that ta-
kes place after understanding is completed and aims
at developing deductions on facts and concepts
acquired. Reasoning is a basic part of deep compre-
hension and involves not only linguistic capabili-
ties (understanding and dialogue) but also deduc -
tion, induction, analogy, generalization, etc., on
common sense and domain specific knowledge. Figure
1 presents a graphic representation of the basic
relationships between understanding and reasoning,
and clearly shows how reasoning moves the internal
representation of an utterance from a first point,
corresponding to surface coprehension, to a second
one that represents deep comprehension.

In the application of online information retrie-
val that we face in this work,the above concepts are
considered in the frame of man-machine communica -
tion, and reasoning will mostly be concerned with
terminology, as we shall further explore in the next
section.

Figure 1. Capturing speaker's goals through natu-
ral language reasoning.

III A SAMPLE APPLICATION :
ONLINE INFORMATION RETRIEVAL

In this section we present an application domain
where the topic of natural language reasoning plays
a fundamental role, namely, natural language access
to online information retrieval services. As it is
well known, online services allow interested users
to solve information problems by selecting and re-
trieving relevant documents stored in very large bi-
bliographic or factual data bases. Generally end-users
are unwilling or unable/ to serach personally and
directly access these large files, but they often
rely on the assistance of a skilful information pro-
fessional, the intermediary, who knows how to select
appropriate data bases and how to design good search
startegies for the retrieval of the desired informa-
tion, and how to implement them in a suitable formal
query language. Usually, the interaction between end-
user and intermediary begins with a presearch inter-
view aimed at precisely clarifying the content and
the objectives of the information need. On tha base
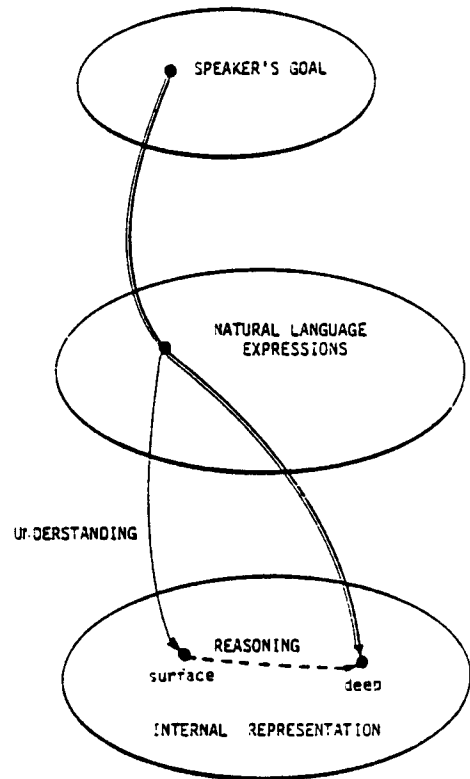of the information gathered, the interemdiary chooses

the most suitable data bases and, with the help of
seraching referral aids such as thesauri, directo-
ries, etc., he devises the search strategy to be
executed by the information retrieval system. The
output of the search is then evaluated by the end-
user, who may propose a refinement and an interac-
tion of the search for better matching his requests.

We claim that the intermediary's task represents
a good example of the issues of natural language rea-
soning, particularly for what concerns the ability of
understanding natural language user's requests and of
reasoning on their linguistic and semantic nuances
in order to fully capture user's needs and goals.
Besides, it has to be stressed that the intermediary
should also posses other important skills, that is
expertise and precise knowledge about data base con-
tent, organization, and indexing criteria, about
availability and use of searching referral aids,about
system query languages and access procedures, and
last about how to plot and construct an adequate
search strategy. The above illustrated chracteristics
motivate the design of a natural language expert sy-
stem for interfacing online data bases. In fact, the

IR-NLI project has among its long term goals the implementation of a system to be interposed between the end-user and the information retrieval system, capable of fully substituting the intermediary's role.

IV   THE IR-NLI SYSTEM

IR-NLI is conceived as an interactive interface to online information retrieval system supporting English language interaction. It should be able to manage a dialogue with the user on his information needs and to construct an appropiate search strategy. More precisely, IR-NLI is aimed at meeting the needs of non-technical users who are not acquainted with on line searching. For this purpose three different capabilities are requested. First, the system has to be an expert of online searching,i.e. it must embed knowledge of the intermediary's professional skill. Second, it must be able of understanding natural language and of carrying on the dialogue with the user. Third, it has to be capable of reasoning on language in order to capture the information needs of the user and to formulate them with appropriate terms in a given formal query language.

In the current first phase of the project we have considered a set of working hypotheses for IR-NLI :

- it operates on just one data base;
- it utilizes only one query language;
- it refers to only one subject domain;
- it is conceived only for off-line use without interaction with the data base during the search session.

7   SYSTEM ARCHITECTURE

The general architecture designed for the IR-NLI system is shown in Figure 2. The kernel of the system is constituted by the STRATEGY GENERATOR , which is devoted to devise the top-level choices concerning the overall operation of the system and to control their execution. It utilizes for its activity a base of expert knowledge (EK) which concerns the evaluation of user's requests, the managament of the presearch interview, the selection of a suitable approach for generation of the search strategy, and scheduling of the activities of the lower level modules UNDERSTANDING AND DIALOGUE, REASONING, and FORMALIZER. The operation of the STRATEGY GENERATOR is organized around a basic sequence of steps, each taking into account a differnt subset of expert rules, that apply to different situations and

fire suitable sequences of understanding, dialogue, and reasoning functions until the internal representation of the user's requests is completely expanded and validated.

The UNDERSTANDING AND DIALOGUE module is devoted to perform activities mostly of linguistic concern. First, it has to translate the natural language user's requests into a basic formal internal representation (IR). Second, it manages the dialogue with the user by generating appropriate queries and by translating his replays,thus expanding the IR with new information. The UNDERSTANDING AND DIALOGUE module utilizes for its operation a base of linguistic knowledge (LK).

The REASONING module is aimed at reasoning on IR in order to enlarge its content with all the information required to generate an appropiate search strategy. It utilizes for this task a base of domain specific knowledge (DSK).

The FORMALIZER module, after the STRATEGY GENERATOR has completed its activity, constructs from the IR the output search strategy to be executed for accessing the online data base. The FORMALIZER utilizes for its operation knowledge about the formal language needed to interrogate the online data base and operates through a simple syntax-directed schema. It is conceived as a parametric translator capable of producing search strategies in several languages for accessing online services, such as SDC ORBIT, Euronet DIANE, Lockheed DIALOG, etc.
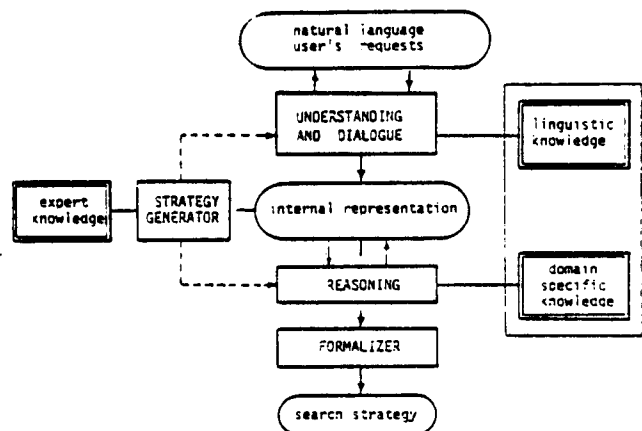

Figure 2. Functions and knowledge bases of IR-NLI.

VI KNOWLEDGE BASES

In this section we shall illustrate the main features of the three knowledge bases utilized by the IR-NLI system.

Let us begin with DSK. The purpose of this knowledge base is to store information about the domain covered by the online data base to which IR-NLI refers. This information presents two aspects : a semantic facet concerning what concepts are in the data base and how they relate to each other, and a linguistic one concerning how the concepts are currently expressed through appropriate terms. The structure of DSK proposed reflects and generalizes to some extent that of classical searching referral aids (in particular, thesauri and subject classifications). At a logical level, it is constituted by a labelled directed network in which nodes represent concepts and directed arcs represent relations between concepts. Each node contains a term, a flag denoting whether the term is controlled or not, a field that stores the posting count, i.e. the number of items in the data base in which the term appear, and a level number which represents the degree of specificity of the term in a hirarchical subject classification. Arcs generally denote the usual cross-reference relationships utilized for structuring thesauri; e.g., BT (broader term), NT (narrower term), RT (related term), UF (used for). In addition, arcs of type next are provided that allow, in connection with the level numbers of nodes, a sequential scanning of the knowledge base according to the currently utilized hierarchical subject classification. This structure is conceived to be directly obtained (possibly in a partially automatic way through appropriate data conversion programs) from available searching referral aids and online thesauri.

Let us turn now to LK. This knowledge base is aimed at supplying all information concerning natural language that is needed to understand user's requests. According to the mode of operation of the UNDERSTANDING AND DIALOGUE module (see section IX), it contains the lexicon of the application domain which is currently considered. Each record of the lexicon contains a word of the language, its semantic type (concept, connective, function), and its meaning. The semantic type denotes the role of a word in a sentence; namely:

- denoting a term of the data base;
- defining a particular relation between different concepts in user's requests;
- specifying a particular function that the user desires to obtain from the information retrieval system.

The meaning of a word may be expressed as a pointer

to a term of the DSK in the case of a word of type concept, as a special purpose procedure in the case of a connective or a function.

Let us note that, in order to avoid unuseful duplication of information in the DSK and LK, a shared directory of entry words may be utilized for both bases.

The purpose of EK is to contain information that concerns the professional expertise of the intermediary on how to manage a search session in order to appropriately satisfy the information needs of the end-user. Its content is made up of several classes of rules concerning the different kinds of activities performed during a search session. The general structure of the rules is of the classical type IF-THEN.

VII STRATEGY GENERATOR

The task of the STRATEGY GENERATOR can be considered from two different points of view :

- an external one, that concerns performing intermediary's activity;
- an internal one, that relates to management and control of REASONING and UNDERSTANDING AND DIALOGUE modules.

On the base of these specifications, it must embed expert capabilities and behave as a consultation system for information retrieval (Politt,1981). The basic mode of operation of this module is organized around the following four main steps that reflect the usual practice of online information searching (Lancaster,1979; Meadow, Cochrane,1981).

1. perform presearch interview
2. select approach
3. devise search startegy
4. construct search startegy.

The IR adopted is unique throughout the whole operation of the system and it is constituted by a frame, initialized by the UNDERSTANDING AND DIALOGUE module,and then further refined and expanded by the reasoning module. This frame is structured into subframes in such a way to contain, classified under different headings, any information that is relevant for searching an online data base, and to allow an effective pattern-matching for the selection of search approaches and tactics. More specifically, IR encompasses terminology about concepts and facets present in user's requests, specifications about search constraints and output format, and figures about search objectives such as recall and precision (Meadow, Cochrane,1981).

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To go further in our description, let us introduce precise definitions of two technical terms above used in an informal way :

search approach : the abstract way of facing a search problem, reasoning on it, analyzing its facets, and devising a general mode of operation for having access to desired information stored in an online data base;
search tactic : a move, a single step or action, in the execution of a search approach.

Let us recall that a search strategy is a program, written in an appropriate formal query language, for obtaining desired information from an online system; taking into account the two above definitions a search strategy can be viewed as the result of the execution of a search approach through application of appropriate search tactics.

Within IR-NLI, a search approach is represented as an algorithm that defines which tactics to utilize, among the available ones, and how to use them in the construction of a strategy. An approach is not however a fixed procedure, since it does not specify at each step which particular tactic to execute, but only suggests a set of candidate tactics, whose execution may or may not be fired.

Tactics are represented at two different levels of abstraction :

- an high-level representation <name, objectives> provided for use by the STRATEGY GENERATOR;
- a low-level representation <name,reasoning actions> supplied for use by the REASONING module.

About 15 tactics are considered, taken from the very rich discussion by Bates (1979) : CORRECT, CUT, SELECT, EXHAUST, REDUCE, PARALLEL, PINPOINT, BLOCK, SUPER, SUB, RELATE, NEIGHBOUR, FIX, RESPELL, RESPACE, etc.

The operation of the STRATEGY GENERATOR is basically pattern-directed; namely, the particular activities to be performed and the way in which UNDERSTANDING AND DIALOGUE and REASONING modules are activated are determined by the content of the current IR (or of some parts of it), which is matched with an appropriate subset of the expert rules. In this way its mode of operation is not strictly determinate : some activities may or may not be fired or may be performed in different ways according to the results of the pattern-matching algorithm.

The activity of the STRATEGY GENERATOR can now be represented in a more detailed way through the following high-level program :

module STRATEGY GENERATOR
initialize search session
  perform presearch interview
    activate UNDERSTANDING AND DIALOGUE
      <generation of IR from first user's requests>
      <pattern-matching with the current IR and selection of subframes that could be appropriately filled up with new information>
    activate UNDERSTANDING AND DIALOGUE
      <engagement of suitable dialogue for gathering additional information about search content and objectives : concepts, limitations, constraints, exclusions, desider precision and recall>
      <expansion of IR>
  select approach
    <selection of the approach which best fits search objectives through pattern-matching between IR and high-level representation of tactics involved in each approach>
  devise search strategy
    <pattern-matching between the current IR and tactics involved in the selected approach>
    <firing of appropriate tactics>
    activate REASONING
      <expansion of IR through execution of reasoning actions>
    activate UNDERSTANDING AND DIALOGUE
      <validation of currently expanded IR>
  construct search strategy
    activate FORMALIZER
      <generation of search strategy from fully expanded IR>
close search session
endmodule

As already mentioned in section IV, in the first version of IR-NLI the off-line operation of the system lead us to consider only the building block approach; future versions of the system will encompass also other classical and commonly utilized approaches such as successive fraction, citation pearl growing, most specific facet first, etc. (Meadow, Cochrane,1981), that are more suitable for an on-line operation of the system in which direct interaction with the data base during the search session is allowed.

VIII   REASONING

The REASONING module operates on the IR and is aimed at precisely capturing user's goals and needs through deductive and inferential processes. More specifically, the REASONING module has the main task of executing the tactics fired by the STRATEGY GENERATOR. Hence, from this point of view, it

represents the actuator of the reasoning process devised by the STRATEGY GENERATOR.

It utilizes the low-level representation of the tactics, which specifies suitable reasoning actions expressed in terms of :

- accessing DSK;
- updating the IR with the new information.

Among the basic capabilitis of the RESONING module we consider generalization to broader terms, extension to related concepts, particularization to narrower terms, analysis of synonymi and homonymi, etc. Its operation is based on special-purpose procedures that correspond to the reasoning actions involved in the tactics. Furthermore, when an action has to be performed on IR for extending its content, validation may be requested from the user in order to ensure a correct matching betwwen his wants and system proposals. This is done through the UNDERSTANDING AND DIALOGUE module which has to gather user's agreement about the new terms to be introduced in the IR.

IX UNDERSTANDING AND DIALOGUE

The purpose of the UNDERSTANDING AND DIALOGUE module is twofold :

- to translate user's requests into IR;
- to generate queries to the user and to understand his answers, i.e. to manage a bounded scope dialogue.

The conception of this module strongly relies, for what concerns the understanding function, on the experience previously developed by the authors with NLI project, and is organized around the concepts of semantics-directed and goal-oriented parsing (Guida,Tasso,1982a). Its mode of operation is mainly rule-based : a main parsing algorithm performs the most elementary steps of the analysis search in the lexicon, construction of a basic tentative internal representation, validation of the basic internal representation, and manages a pattern-directed invocation of heuristic rules for resolution of critical events (e.g., ambiguities, ellipses, anaphoric references, indirect speech, etc. . An important feature of the understanding function is the ability to solve critical situations by engaging the user in a clarification dialogue activated by some of the above mentioned heuristic rules, to gather additional information which is necessary to correctly understand the input natural language requests.

For what concerns the dialogue function, it relies on two strictly connected activities :

- generation of a query, according to some requests from the STRATEGY GENERATOR or REASONING modules, through assembly and completing of parametric text fragments stored in the UNDERSTANDING AND DIALOGUE module;

- understanding of the user's answer and refinement, i.e. validation, updating or completing, of the current IR.

Let us stress that, according to the basic goal-oriented conception of the parsing mechanism of UNDERSTANDING AND DIALOGUE module, the understanding activity performed in the frame of the dialogue function is strongly directed by knowledge of the query that the system has asked the user and, therefore, of expected information to be captured in the answer.

X A SAMPLE SEARCH SESSION

In this section we present a short example of the basic mode of operation of IR-NLI. Figure 3 shows a sample session in which, in addition to the user-system dialogue, parts of the IR and the search strategy generated (in Euronet DIANE EURO-LANGUAGE) are reported. The example refers to the domain of computer science.

XI CONCLUSION

In the paper the main features of the IR-NLI system have been presented. The project is now entering the experimental phase that will be carried on on a VAX 11/780 system.

The design activity so far developed (Guida, Tasso,1982b,1982c) has reached, in our mind, a quite assessed point so that future work on this topic will be mainly concerned with removal of the restrictions and working hypotheses considered in the current first phase and with refinement of implementation details. The authors also plan to implement in the next future a complete prototype version of the system to be connected to a real online system in the frame of a strictly application oriented interest.

The research activity will be focused, on the other hand, on several issues that deserve further

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> PLEASE SPECIFY YOUR REQUEST !
* I would like to have information about intelligent terminals for online information
  retrieval

IR :   concept-1 : INTELLIGENT TERMINALS
       concept-2 : ONLINE INFORMATION RETRIEVAL

> DO YOU PREFER AN HIGH RECALL OR AN HIGH PRECISION SEARCH ?
* an high recall one
> DO YOU HAVE ANY PARTICULAR POINT OF VIEW TO CONSIDER FOR THIS RESEARCH ?
* yes, cost considerations
> ANY OTHER ONE ?
* no
> DO YOU LIKE ONLINE OR OFFLINE PRINTING OF RESULTS ?
* please supply offline printing
> PLEASE SPECIFY THE FORMAT : WITH OR WITHOUT ABSTRACT ?
* with abstract

IR :   .
       .
       concept-3 : cost
       recall    : HIGH
       output    : OFFLINE, FULL FORMAT

> BUILDING BLOCK APPROACH SELECTED
> TRYING TACTICS :
                   SELECT
                   PARALLEL
                   RELATE
                   RESPELL
                   RESPACE
> THE CONCEPT "ONLINE INFORMATION RETRIEVAL" COULD BE SPLITTED INTO :
  - ONLINE
  - INFORMATION RETRIEVAL
  PLEASE VALIDATE !
* yes
> THE FOLLOWING ADDITIONAL TERMINOLOGY IS PROPOSED FOR THE CONCEPT "ONLINE" :
  INTERACTIVE, REALTIME
  PLEASE VALIDATE !
* ok
.
.
> THE CONCEPT "ONLINE" COULD BE EXPRESSED THROUGH THE FOLLOWING TERMS :
  ONLINE, ON LINE, ON-LINE
  PLEASE VALIDATE !
* ok
.
.
> SEARCH STRATEGY GENERATED :

  1. FIND INTELLIGENT.TERMINALS
  2. FIND ONLINE OR ON.LINE OR INTERACTIVE OR REALTIME OR REAL.TIME
  3. FIND INFORMATION OR REFERENCE OR BIBLIOGRAPHIC$ OR RETRIEV$ OR SEARCH$
  4. FIND COST$ OR PRICE
  5. FIND S=1 AND S=2 AND S=3 AND S=4
  6. PRINT F1
> END OF SEARCH SESSION, BYE
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Figure 3. Sample search session with IR-NLI.

investigation. Among these we mention :

- the development of more flexible and robust dialogue capabilities, including limited justification of the mode of operation of the system (Webber,1982);
- the study of advanced representations of tactics through generalized rule structures that will allow more refined matching and firing mechanisms (Winston,1982);
- the design of new tactics (e.g., PATTERN, RECORD, BIBBLE (Bates,1979)) and reasoning actions, that enable the system to keep track of previous search sessions and to analogize from experience in devising and executing a search approach.

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