RESEDA, AN INFORMATION RETRIEVAL SYSTEM USING ARTIFICIAL INTELLIGENCE AND KNOWLEDGE REPRESENTATION TECHNIQUES

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ABSTRACT.

The RESEDA project is concerned with the construction of AI Information Retrieval systems working on databases containing biographical data. There exist in RESEDA two fundamental ways of retrieving information requested by a user. In the first case, the information we wish to obtain is data which already exists in the base. This data can be obtained by direct match with the "search model" corresponding to the user's question. If this is not possible, we can still try to get an answer by using the inference procedures of the "transformation" type. The second method retrieves information which, in contrast, is created **ex nihilo** by the search procedure itself. It expresses, in fact, the possibility of a new **causal relationship**, within the base, between an "episode" provided explicitly by the user and one or more "episodes" that the system retrieves by applying an inference procedure of the type "hypothesis".

1. INTRODUCTION.

This paper aims to provide a brief description of RESEDA's conceptual tools ; RESEDA is an Information Retrieval system equipped with "deep level" [1,2] reasoning capability in the field of complex biographical data management. The term "biographical data" must be understood in its broadest possible sense : that is, any event, in the public or private life, physical or intellectual, etc., that is possible to gather about the personages we are interested in. In the present state of the system, this information concerns a well-defined period in time (approximately between 1350 and 1450) and a particular subject area (French history). We are presently involved in some preliminary studies concerning the feasability of adapting RESEDA's methodology to the processing of other biographical data, see 5., "CONCLUSIONS".

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2. FUNDAMENTAL CONCEPTS OF THE RESEDA SYSTEM.

RESEDA differs greatly from "traditional" information retrieval systems.

Firstly, the information stored in the system's database is not in the form of "documents" in the usual sense of the term ("full text" or bibliographical references) but in the form of "facts" : every "episode" in the lives of our personages which it is possible to collect and represent. The sources of the stored documentation are thus very varied ; in the case of the existing prototype (mediaeval history of France) the sources include : original documents, learned contemporary works, articles from journals, etc.

A second difference concerns the objectives of the search procedures operating in the system.

With RESEDA the aim is, on the one hand, to carry out an "intelligent" retrieval of the stored information ; that is to say, for example, that the system has the ability "to come up with information that is not exactly what was asked for, but nevertheless fits the bill" [3:94] ; and on the other hand, that the system has the ability, at least to a certain extent, to automatically establish relationships between facts stored in the system.

These aims obviously determine the choice of the computing tools to be used within the RESEDA framework :

- The representation of data in the system must be of the type "semantic", since it is their "meaning" which is to be operated upon and not their original "surface" linguistic form ;

- The most important characteristic of the system is its systematic use of inference procedures. I shall give some information here on this subject, referring to section 4. for more details.

There are two types of inference procedures in RESEDA : "transformations" and "hypotheses".

Transformations are concerned with retrieving and using any latent knowledge (implicit information) that may exist in the system. For example, it is reasonable to assume that a given person has followed a University course, even if this information is not given explicitly in the base, if we can retrieve the information that the person in question holds the diploma corresponding to the course he is meant to have followed ; the second fact usually implies the first.

The hypotheses, on the other hand, focus on the specific purpose of creating **ex nihilo** previously inexistant knowledge in the specific field of causal relationships. More specifically, the hypotheses can isolate inside the database a number of "facts" and suggest them to the user as plausible explanations of some other known fact, by establishing between the two groups a causal relationship. Thus we could, for example, try to explain changes in top-level state administration by a change in political power.

3. SOME INFORMATION ABOUT THE SEMANTIC CODING.

To perform complex inference operations, we obviously need some form of "rich representation" for any type of information stored in the system.

3.1 The coding of biographical information.

As for biographical data, the representation we chose is basically a kind of "case grammar", according to the particular meaning attached to the term in an AI context [4,5,6] ; as will become obvious later, all the other kinds of representation used in the system - for the inference rules, for example - are simply generalizations of the one adopted for the data.

The biographical information which constitutes the system's database is organized in the form of units called "coded episodes" or "planes". There are several different types of plane ; the "predicative plane", the most important, corresponds to a "flash" which illustrates a particular moment in the "life story" of one or more persons. A predicative plane is made up of one of five possible "predicates" (BE-AFFECTED-BY, BEHAVE, BE-PRESENT, MOVE, PRODUCE), to which one or more "modulators" may be attached. The function of the modulators is to specify and delimit the semantic role of the predicate. Of course, the "meaning" of the modulator plus predicate is "defined" - as for all elements of the RESEDA data definition language ("metalanguage") - by the general behaviour of the system rather than by the usual function of these codes in natural language - see also Hayes [7:11-12]. The predicate of the plane is accompanied by "case slots" which introduce the predicate arguments.

Information concerning dates and locations is also given in the predicative plane, as is the bibliographic authority for the statement. Predicative planes may be linked either through the label of one plane being the value of an argument slot (the slot OBJ) in another, or through explicit links "and", "or", "cause", "finality", etc.

The extremely simple example given in figure 1 should provide a clearer idea of what I have just explained. It is the representation of "Robert de Bonnay was named '**bailli**' of Mâcon on 27th September 1413 by the King's Council" (bibliographical authority : Demurger) ; the **bailli** was a high level civil servant who dispensed justice, administered finances, etc., for a particular area, the **baillage**, in the name of a king or lord. The codes given in capital letters indicate the predicate and the cases associated with it.

For each predicative plane there is a pair of temporal markers, "date1-date2", which give the duration of the episode. In the above example, which concerns a change of state (modulator "begin") associated with a punctual event, the second date slot (date2) is empty. The presence of the modulator "soc" (social) and of a "SOURCE" conforms to the fact that Robert de Bonnay's investiture is situated in a socio-professional

```
1) begin+soc+BE-AFFECTED-BY  SUBJ    Robert-de-Bonnay
                             OBJ     bailli:Mâcon
                             SOURCE  king's-council:Paris
                             date1 : 27-september-1413
                             date2 :
                             bibl. : Demurger1,234
```

figure 1 : An example of a predicative plane

context. "Robert-de-Bonnay" is a label (address) pointing to the group of coded episodes available in the system which concern the corresponding historical personage ; "**bailli**" (meaning the "post of **bailli**") and "king's-council" are entries in RESEDA's lexicon. The classifications associated with the lexical terms provide essential information for the system as regards the historical background of the period. "Mâcon" and "Paris" are obviously the "object location" and the "source location" respectively. If the historical documents gave us explicitly the precise causes of this nomination, then the corresponding planes would be introduced into the database and the "nomination" plane would be associated with them by means of an explicit link of the "cause" type.

3.2 The "search model" concept.

When the system is considered from the point of view of its utilization, the fundamental concept which must be introduced is that of the "search model". A search model gives the essential elements, expressed in terms of the RESEDA metalanguage, of a coded episode which it is necessary to search for in the database. A search model may originate from outside the system, if it is the direct translation of a query posed by the user. On the other hand, it may be automatically generated by the system, as will be clarified later on, during the execution of an inference procedure.

Let us suppose, then, that the user questions RESEDA on the subject of the progression of Robert de Bonnay's career, asking, for example, "Did Robert de Bonnay exercise the power of **bailli** during the first quarter of the 15th century". In this case, the user himself creates the search model given in figure 2, with the aid of a prompting program. The only notable difference between this formalism and that required for representation of the episodes in the database is the presence of a "search interval", "bound1-bound2", which is used to define the temporal limits of the search. Therefore, the search interval has the function of limiting the planes to be examined, and has only an indirect relationship with the temporal information of the "date" type which is associated to each of the episodes recorded in the base.

```
BE-AFFECTED-BY  SUBJ    Robert-de-Bonnay
                OBJ     bailli
                bound1 : 1400
                bound2 : 1425
```

figure 2 : A simple "search model" enabling the retrieval of the plane in figure 1

I do not intend, here, to go into the details of the procedure adopted to test the matching of a search model with data in the base ; instead, for details of this, see Zarri [8], Zarri **et al.** [9,10]. It is obvious, for example, that the model in figure 2 may be directly matched with the plane in figure 1. This, of course, is the exception rather than the rule.

4. RESEDA'S INFERENCE RULES.

The system's inference rules are formulated using a generalization of the metalanguage used for the biographical data. This generalization is achieved mainly through the introduction of variables, which allows us to write inference rules applicable to a large class of events. The "restrictions" associated with these variables specify the group of values which can be associated with each of them, and thus define the field in which the inference rule can apply.

4.1 Transformations.

If we reach a dead end when trying to match a search model with data in the base, a first class of inference rules may be applied ; these are the "transformations".

To keep to an extremely simple example, consider the transformation of figure 3, allowing us to change a search model formulated in terms of "end+BE-PRESENT" into a new one in terms of "MOVE", which can be submitted, in turn, to the usual match procedures. This formal rule translates the common sense rule "If someone goes from one place to another, he has certainly left his starting point" : the justification of the use of substitution in figure 3 lies in the fact that any information about some personage **x** having moved from **k** to **l** is at the same time a response to any query about the possibility of his no longer being at place **k**. Note that, in the terms of RESEDA's metalanguage, the movements of a personage are always expressed in the form of a subject **x** which moves itself as an object.

t1) end+BE-PRESENT SUBJ **x** : **k** ➞ MOVE SUBJ **x** : **k**
OBJ **x** : **l**

x = <personage>
k,**l** = <location>
k $\neq$ **l**

figure 3 : A simple inference rule of the "transformation" type

On a formal level, it is worthwhile noting that the "variables" which appear in the original search model (**x** and **k** in figure 3) must normally appear in the transformed model and/or in the "restrictions" associated with the new variables (**l** in figure 3) introduced at the level of this transformed model, see rule t1. This ensures the logical coherence between the two parts of the transformation ; the model on the right hand side must indeed "imply" the one on the left. The values which replace the variables in the retrieved plane (or planes) using the transformed model must obviously respect the restrictions associated with all the variables which appear in the transformation.

A second specimen of transformation is that given in figure 4 ; it concerns the "University course" example that I evoked at the end of section 2. The common sense rule underlying the formalism of figure 4 is : "If a person **x** has a university degree **w**, then this person has followed some course **v**" (one or several persons **y** have "produced" the course **v** with the intention of **x**). In the transformation in figure 4, the variable

```
t2) PRODUCE  SUBJ y ──► BE-AFFECTED-BY  SUBJ x
             OBJ  v                     OBJ  w
             DEST x

x = <personage>
y = <personage>|<personages>
x ≠ y
v = <university-course>
w = <degree-obtained>
w = f(v)
```

figure 4 : The "University course" transformation rule

v of the original search model appears in the terminal model at the level of the restrictions associated with the new variable **w**; "**w** = f(**v**)" is an abbreviated way of expressing that there must be coherence between the diploma obtained and the course followed.

There is one last remark to be made about transformations, which concerns the two in figure 5, written for simplicity's sake in natural language. In this case, the rule about the repercussion of the variables on the left on the right hand side takes the form of a "condition" which must be met before the transformation can be allowed ; the substitution of the model on the right hand side for the one on the left forces us to check for the existence of episodes within the base which are able to guarantee the appropriate context. Transformations of this kind are called "conditional transformations".

t3) try to verify the attachment of **x** to the important person **z** ──► try to verify the attachment of **y** to the important person **z**

on the condition that : verification of a fairly close relationship, for example kinship, between **x** and **y** may be found

t4) try to verify that **x** belongs to party **v** ──► try to verify that **x** fights against party **w**

on the condition that : it is possible to show that, during the period in question, **v** and **w** (e.g. Armagnacs and Bourguignons) were openly opposed

figure 5 : Two examples of "conditional transformation"

I shall conclude by pointing out that the use of concepts comparable with RESEDA's "semantic transformations" is quite common when using AI techniques to exploit a factual database, see for example "elaborations" in Kolodner [11] , "expansions" in McCarty and Sridharan [12], "extensions" in Hafner [13], etc.

4.2 Hypotheses.

Even taking into consideration this first category of inference rules, the behaviour of the system such as it has been described up to now is rather classic in type. There is, however, a second, more original way of searching in RESEDA : it is possible to search for the hidden "causes", in the broadest sense of the word, of an attested fact in the base. For example, if the user, in submitting the query in figure 2, obtained in reply the plane in figure 1, and if we assume that the "reasons" for the nomination are not explicitly recorded in the database, we will now be able to ask the system to automatically produce a **plausible** explanation of this fact by using a second category of inference rules, the "hypotheses".

In order to give an initial idea, on an intuitive level, of the functioning of the hypotheses, figure 6 shows the formulation in natural language of four characteristic hypotheses

h1) ... one might cease to act on behalf of some other person

BECAUSE

one has abused that person's confidence (e.g. by misrepresenting his view to a third party)

h2) ... one might leave something (in one's will) to a (religious) community

BECAUSE

one had some special connection with this community

h3) ... one might take a particular attitude in an argument

BECAUSE

one has close links with one of the parties in a conflicting situation

h4) ... one might be chosen for a (official) post

BECAUSE

one is attached to a very important personage who has just taken power

figure 6 : Formulation in natural language of four characteristic "hypotheses" of the RESEDA system

of the RESEDA system. The first part of each of the rules corresponds to a particular class of confirmed facts (planes) for which one asks the "causes". For example, the plane in figure 1 is clearly an exemplification of the first part of the fourth hypothesis in figure 6. In RESEDA's terminology, the formal redaction of this first part is called a "premiss". The second part (the "condition") gives instructions for searching the database for information which would be able to justify the fact which has been matched with the premiss. That is, if planes matching the particular search models which can be obtained from the "condition" part of the hypothesis can be found in the database, it is considered that the facts represented by these planes **could** constitute the justification for the plane-premiss and are then returned as the response to the user's query. When trying to match the models obtained from the condition the system can, of course, use inferences of the type "transformation".

Let us now look in some detail at the hypothesis h4 of figure 6. A whole family of inference rules expressed in RESEDA's metalanguage corresponds in reality to the natural language formulation given in h4 ; one of these realizations is shown in figure 7. A description of the procedure followed to isolate the elements of these families can be found in [14] ; see also [15] for the general methodology for constructing hypotheses.

The meaning, in clear, of the formalism in figure 7 is as follows (see also h4 in figure 6) : to explain what brought the administration **n** to give post **m** to **x**, the hypothesis suggests we check in the system's memory for the following two facts, which must be verified simultaneously (operator "∧", "and") :

A) **x** was employed by an important person **y** (the seigniorial administration **p** specific (SPECIF) to **y** was "augmented" by **x**) during a period which includes the time when **x** was nominated to post **n** ;

B) at a date that coincides with, or is previous to, the date of nomination **d1**, the administration **n** comes under the leadership of **y** (**n** starts to have **y** for chief (lid = leader)).

```
   premiss : α

   α) begin+soc+BE-AFFECTED-BY  SUBJ     x
                                OBJ      m
                                SOURCE   n
                                date1 :  d1
                                date2 :

   restrictions on the variables of the premiss scheme :

   x = <personage>
   m = <monarchic-post>|<seigniorial-post>
   n = king's-council|lord's-council
if m = <monarchic-post> then n = king's-council
if m = <seigniorial-post> then n = lord's-council

   condition : A ∧ B

   A) BE-AFFECTED-BY  SUBJ      p(SPECIF y)
                      OBJ       x
                      bound1 :  b1
                      bound2 :  b2

   B) begin+lid+BE-AFFECTED-BY  SUBJ      n
                                OBJ       y
                                bound1 :  b3
                                bound2 :  b4

   restrictions on the variables of the condition schemata :

   b1 < d1 < b2
   b3 < d1 = b4
   y = <personage>
   x ≠ y
   p = <seigniorial-organization>
```

figure 7 : Formal representation of one hypothesis in the family "nomination to an official post"

```
2) BE-AFFECTED-BY  SUBJ     prince's-court (SPECIF Charles-d'Orléans):
                                           Blois
                   OBJ      Robert-de-Bonnay (SPECIF chamberlain)
                   date1 :  8-april-1409
                   date2 :  (1415)
                   bibl. :  Demurger1,234
```

"Robert de Bonnay held the post of chamberlain to the Duc d'Orléans (the court of Charles d'Orléans, whose residence was at Blois, was 'augmented' by Robert de Bonnay) from 8 April 1409 until 1415 (date not confirmed by documents, but reconstituted by the historian)"

```
3) begin+lid+BE-AFFECTED-BY  SUBJ   king's-council:Paris
                             OBJ    (COORD Louis-d'Anjou
                                    Charles-d'Orléans Jean-de-Bourbon
                                    Dauphin-Louis Jean-de-Berry
                                    Bernard-d'Armagnac):Paris
                             date1 : 1st-september-1413
                             date2 :
                             bibl. : consensus
```

"On the 1st September 1413, the leaders of the faction favourable to the Duc d'Orléans (the future 'Armagnac party') took control ('lid' = leader) of the administration of the state. This information is provided by the 'consensus' of historians, who are specialists in this period"

figure 8 : Predicative planes provided as a reply to the question regarding the "causes" of the nomination of Robert de Bonnay by the hypothesis in figure 7

Figure 8 gives the planes obtained by means of this hypothesis in the case of the query about Robert de Bonnay's nomination. The formulation in the metalanguage of this event of courses matches, see figure 1, the premiss in figure 7 ; these planes can thus provide a plausible explanation for the nomination.

From an algorithmic point of view, searching for this type of solutions is achieved by exploring a choice tree **exhaustively** in a depth-first way with backtracking. This tree exploration procedure brings about a series of complex actions, from the binding of variables after decoding the "conditional restrictions", to the automatic definition of temporal slices to be explored in the biographical database, etc. The "conditional restrictions" are used to specify the relationships which must exist between the groups of values which can be associated with two or more variables. Thus, in the example of figure 7 (see the "restrictions on the variables of the premiss schemata"), if the position which changes occupant depends on the royal administration, the source of the nomination cannot be a seigniorial council. Note that the use of variables and restrictions allows us to build inference rules of very great complexity and bearing.

5. CONCLUSION.

The RESEDA project will be developed in two different directions.

In a first approach, which could be seen as "pragmatic", we shall attempt to test the adaptability of the prototype, as it exists today, to other types of biographical data. For example, an application of RESEDA in the field of medicine has already been defined ; this concerns the study of medical files on cancerology, trying to complement the information usually found in such files with personal, cultural, socio-economical, family or environmental factors which are often responsible for the variability and imprecision of diagnostics. Other possible applications of RESEDA's methodology concern the legal and military domains.

A second, more theoretical direction for the development of RESEDA, foreshadows a generalization of the computational solutions adopted for the system prototype. Studies in this direction are centred round four main themes :

- to develop and generalize the system for Knowledge Representation proper to RESEDA, including in this theme the widening of the semantic framework, which defines the hypothesis inference rules, allowing for relationships other than causal ones ;
- to introduce into the existing Inference Interpreter the possibility of "intelligent" execution of the rules, allowing, for example, the execution of a rule doomed to fail to be stopped in order to procede with a more appropriate one, thus avoiding over-rigid and expensive backtracking ;

- to automate, as far as possible, the very complex strategy (applied manually at the moment) necessary to isolate and formalize the system's inference rules [14], in order to achieve some kind of automatic knowledge acquisition.

- to permit the database to be constructed at least partly automatically, by developing "machine translation " techniques to pass from an initial formulation in natural language of information to be introduced into the system, to its representation in the terms of RESEDA's metalanguage - preliminary results have already been obtained in this area, see [16,17].

6. **REFERENCES.**

[1] Davis, R., Expert Systems : Where are we ? And where do we go from here ?, The AI Magazine 3 (1982), n° 2, 3-22.

[2] Hart, P.E., Directions for AI in the Eighties, ACM Sigart Newsletter n° 79 (1982) 11-16.

[3] Schank, R.C., Kolodner, Janet L., and DeJong, G., Conceptual Information Retrieval, in : Oddy, R.N. et al. (eds.) Information Retrieval Research (Butterworths, London, 1981).

[4] Bruce, B., Case Systems for Natural Language, Artificial Intelligence 6 (1975) 327-360.

[5] Rosner, M., and Somers, H.L., Case in Linguistics and Cognitive Science, Working Paper n° 40, Fondazione Dalle Molle, Université de Genève (1980).

[6] Charniak, E., The Case-Slot Identity Theory, Cognitive Science 5 (1981) 285-292.

[7] Hayes, P., The Naive Physics Manifesto, Working Paper n° 34, Fondazione Dalle Molle, Université de Genève (1979).

[8] Zarri, G.P., An Outline of the Representation and Use of Temporal Data in the RESEDA System, Information Technology: Research and Development, in press.

[9] Zarri, G.P., Ornato, Monique, Lee, G., Lelouche, R., Meissonnier, V., and Insole, Angela, Projet RESEDA/1 : Rapport sur les recherches effectuées du 1er mai 1979 au 1er octobre 1979, Rapp. LISH/150, Laboratoire d'Informatique pour les Sciences de l'Homme, CNRS Paris (1979).

[10] Zarri, G.P., Ornato, Monique, Lee, G., Lelouche, R., Meissonnier, V., De Vries, P., and Roccati, M., Projet RESEDA/1 : Rapport sur les recherches effectuées du 1er octobre 1979 au 1er juillet 1980, Rapp. LISH/187, Laboratoire d'Informatique pour les Sciences de l'Homme, CNRS Paris (1980).

[11] Kolodner, Janet L., Retrieval and Organization Strategies in Conceptual Memory : A Computer Model, Research Report n° 187, Computer Science Department, Yale University (1980).

[12] McCarty, L.T., and Sridharan, N.S., The Representation of Conceptual Structures in TAXMAN II, Part One : Logical Templates, Report LRP-TR-4, Laboratory for Computer Science, Rutgers University (1980).

[13] Hafner, Carole D., An Information Retrieval System Based on a Computer Model of Legal Knowledge (UMI Research Press, Ann Arbor, 1981).

[14] Zarri, G.P., Building the Inference Component of an Historical Information Retrieval System, in : Proceedings of the 7th International Joint Conference on Artificial Intelligence - IJCAI/7 (The American Association for Artificial Intelligence, Menlo Park, 1981).

[15] Zarri, G.P., What Can Artificial Intelligence Offer to Computational Linguistics ? The Experience of the RESEDA Project, in : Ager, D.E. et al. (eds.) Advances in Computer Aided Literary and Linguistic Research (University of Aston, Birmingham, 1979).

[16] Léon, Jacqueline, Memmi, D., Ornato, Monique, Pomian, Joanna, and Zarri, G.P., Conversion of a French Surface Expression into its Semantic Representation According to the RESEDA Metalanguage, in : Horecky, J. (ed.) COLING 82 - Proceedings of the Ninth International Conference on Computational Linguistics (North-Holland, Amsterdam, 1982).

[17] Zarri, G.P., Automatic Representation of the Semantic Relationships Corresponding to a French Surface Expression, in : Proceedings of the Conference on Applied Natural Language Processing (Association for Computational Linguistics, Menlo Park, 1983).