A Cooperative Expert System Behave as a Finite Automata

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Abstract

The architecture of a Cooperative Expert System (CES) that behaves as a finite automata is presented, that is to say, it is a quintuple <G, M, CT, Gj, K> where G is the set of knowledge bases Gj, M is the set of messages, CT is in state of transition, function λ which in this case is a communication protocol represented by a matrix or Communication Table (CT) and with which can pass from one Knowledge Base (KB) to another, these elements behave as the automata's states, Gj is the initial KB determined by an enunciated source given by the user, and finally, K is the set of selected KB's or candidates to consultation. In the case of the finite automata, the set K comes to be the set of final states. All the Knowledge Bases that visit one have a common working area where the results of the inferences are read and deposited, this way the Expert Systems which cooperate in a consultation utilise those data without having to ask the user.

Keywords: Stratified knowledge based, expert systems, multiple expert systems

Introduction

The main objective of this work is to show the architecture of a Cooperative Expert System (CES) that behaves as a finite automata. The architecture of the CES's solves problems that require shared information that come from different Knowledge Bases (KB's).

To solve the cooperation problem, the proposed architecture allows to establish a communication between one or more KBs using a text in natural language that the user uses of a particular problem. This architecture focuses in relative KBs to the semantics that the user utilises in his enunciated source as the initial fact and with which explains his problem. The idea is to communicate the KBs in the moment that the CES requests the communication at time of execution.

So far, diverse Expert Systems have been modeled (ES's) to solve the communication problem among ESs, because this contributes to the solution of problems which characteristics involve more than one KB (Chiang-Choon, 1991) (Dai, 1993) (Jenkins, 1994) (LeClair, 1989). This means that it is about problems that are solved with more than one human expert or more than a domain of experience (Oliveira, 1991) (Pardue, 1993). Also in some cases it suits to have sources of information of several processes to export results to KBs which are required in other ESs. To solve the problem of the communication of ESs induces to the simulation of processes that require domains of multiple experience (Silverman, 1988 1989) (Wolf, 1989) (Wong, 1993). In the communication problem among ESs, board architectures have generally been used (Hayes-Roth, 1983) (Balzer, 1980), that consist basically in the working area common to all the ESs formed with different bases of information, which are independent from one another. The board can be erased or modified, however the structure is rigid in relation to the communication concept.

The communication among ESs is a problem that involves a great variety of research topics when trying to establish an exchange of information among them. The publications on the topic are truly scarce and of those that exist, only show partial results (Hadj, 1994).

The idea of integrating interaction and cooperation in the development of systems based on knowledge has grown during the last few years and these facts " interaction " and " cooperation " give the cooperative ESs characteristics (Chandrasekaran, 1986) (Fabiano 1994).

In (González,1991) the cooperation problem is treated by using an enunciated source that the user uses like initial fact to be placed in a neighbourhood of the KB, with the idea of avoiding the navigation in the whole KB. From this position arises the necessity of solving the problem of dividing a KB in generic parts, where each part is a KB. As these divisions include generic knowledge, they were called themes. A theme is a text or matter on which a speech turns it is really structured and generic knowledge. In the following paragraphs the terms neighbourhood, area or division of a KB are synonymous of theme in this document (González, 1990a).

The generic areas in a KB were thought with the purpose of solving the navigation problem in the KB, as commonly done when an ES of first generation (Shortliffe, 1976) (Duda, 1978) (Buchanan, 1985) tries to confirm a goal. Also with these areas, the idea of communicating two or more KBs arose for the treatment for a same problem. This way the cooperation is obtained in automatic form and problems can be treated which require more than a human expert. The work that is presented solves in a simple way this type of cases, that is to say, to share the information or to extend the knowledge of one or several KBs to solve domain problems of multiple experience (González, 1989)

The incognito on how to be placed in the mentioned neighbourhood of the KB through the enunciated source was solved by means of characteristic words (they are found in the elements of the KBs) and distinguish the areas of the KB regarding the user's text. The characteristic words were denominated key words, and with these, areas of knowledge were identified, that is to say, the key words mark the difference between two themes from a semantic point of view, for example " shock " is a key word in a topic that refers to the suspension of a car or simply with the suspension (González, 1990b). Therefore a key word, can be a component or part of a device, attribute or anything that can indicate some semantic content to identify the theme.

To locate these areas in a KB, different questions were expounded, such as: what should be done in case the user's text involves more than an area of interest?, how can the results be shared with other areas?, how is the data of some rules of an area X produced in another area Y obtained? or if being in the area X, how can the data questioned to the user in an area Z be transmitted to the area X indirectly?; detecting relative vicinities to the user's text in a base of knowledge resulted interesting and excessively complicated.

Also other questions arose: Is the problem outlined by means of the statement source solved completely by means of the set of KBs selected?, does a measure of effectiveness exist in this type of systems?, is a registration of the resolved problems taken?, How to take advantage of the results of similar problems for future consultations? How is the reasoning line explained when several ESs intervene?, etc.. Some questions were not resolved because they are true research topics.

To find the areas or relative vicinities to the user's text, it was analysed and was seen that instead of treating the elaborated KB, it would be better to work with the discourse domain or reference mark fragmenting it and building a KB for each division. The discourse domain or reference mark, are a fragment which reality allows us to visualize each one of the events that happen and how the relationships among his objects are revealed in all their magnitude. Due to the complexity of such a situation, the discourse domain was treated as an invented field, artificial, in which the objects, properties and possible events are clear and closely defined in advanced.

The union of all the topics results, as consequence, the global KB of the whole domain. It was found that the division of speech domain induced a division in a previously built global KB in that domain. When such divisions were carried out, some components of rules premises or conclusions (atoms or key words) of a relative KB to a division of the discourse domain were detected. They were found sharing with rules of one or more divisions resulting that the KB of a division was included (as if it was incrusted) in other KBs of other divisions, for what the union of all the KBs of each division was called **knowledge base stratified in themes**.

The themes lead to a better definition of the knowledge because it is easier to model on the divisions of the discourse domain and the problem of being located in an area of the KB using the user's text is simple.

The user's text is used to select the themes or KBs, which will be employed for consultation. To be placed or select a theme, a set of **Paired Key Words** was assigned, which was called **inventory**. This set is a binary relationship, and therefore has associated a directed graph that makes easier to observe the relationships among the key words. This way, the **inventory** is a directed graph of key words. It is feasible to assign, as inventory to each theme. A semantic net instead of the directed graph can be used, but that is another research topic and it won't be discussed here.

It is noteworthy to comment that the CES (González 1991) behaves as a finite automata, that is to say, a quintuple $<G, M, TC, G_j, K>$, where instead of having a set of K states, we have a set of KBs G, instead of an alphabet Σ, we have a set of messages M, instead of a function of transition λ, we have a TC (communication chart), instead of having an initial state q_0, we have an initial Knowledge Base G_j for some $_j$ of the KBs selected by the enunciated source and the most important according to its factor of relevance, and finally instead of having a combined F of final states, we have a set K of bases of selected knowledge or candidates to consult.

Cooperative Expert systems

The Cooperative Expert Systems (CES) are characterised because their architecture is less monolithic than those of first generation, as they deal with different bases of knowledge for the solution of a problem, as show in figure 1.

Some works on this type of CES exist, but so far it has not been found in the literature one that has the characteristics of sharing information at time of execution, mainly when working with several bases of knowledge selected according to the information of a user in natural language as entrance data. Here the architecture presented which can be compared with a finite automata.

The architecture of this CES resulted from the solution of a problem of general type where the main intention was to begin the dialogue with the ES and not the other way around, as traditionally done with ES of first generation. Truly, the problem to solve is:

"Given a KB, the consult initiation is wanted starting from a detected area of the KB by means of a text that the user utilises to explain his problem, and in the event of being required one or more areas of the KB, establish the communication among these."

An equivalent form of this proposition is:

"Given the user's information in a text, and a set of KBs, select one and configure an ES relative to that KB, and in the event of requiring information from other KBs, establish the communication whichever is necessary among these."

Formally the definition of the problem turns out to be:

Hypothesis: Given: an enunciated source T in natural language and a domain of experience in the form $G=\{G_1,G_2,\ldots ,G_n\}$ where:

$G_i = <BH,BR>$
$BH = \{H_1,H_2,\ldots ,H_m\}$ is the base of facts and
$BR = \{r_1,r_2,\ldots ,r_k\}$ is the base of rules, the elements r_i with i=1,..k has the form:

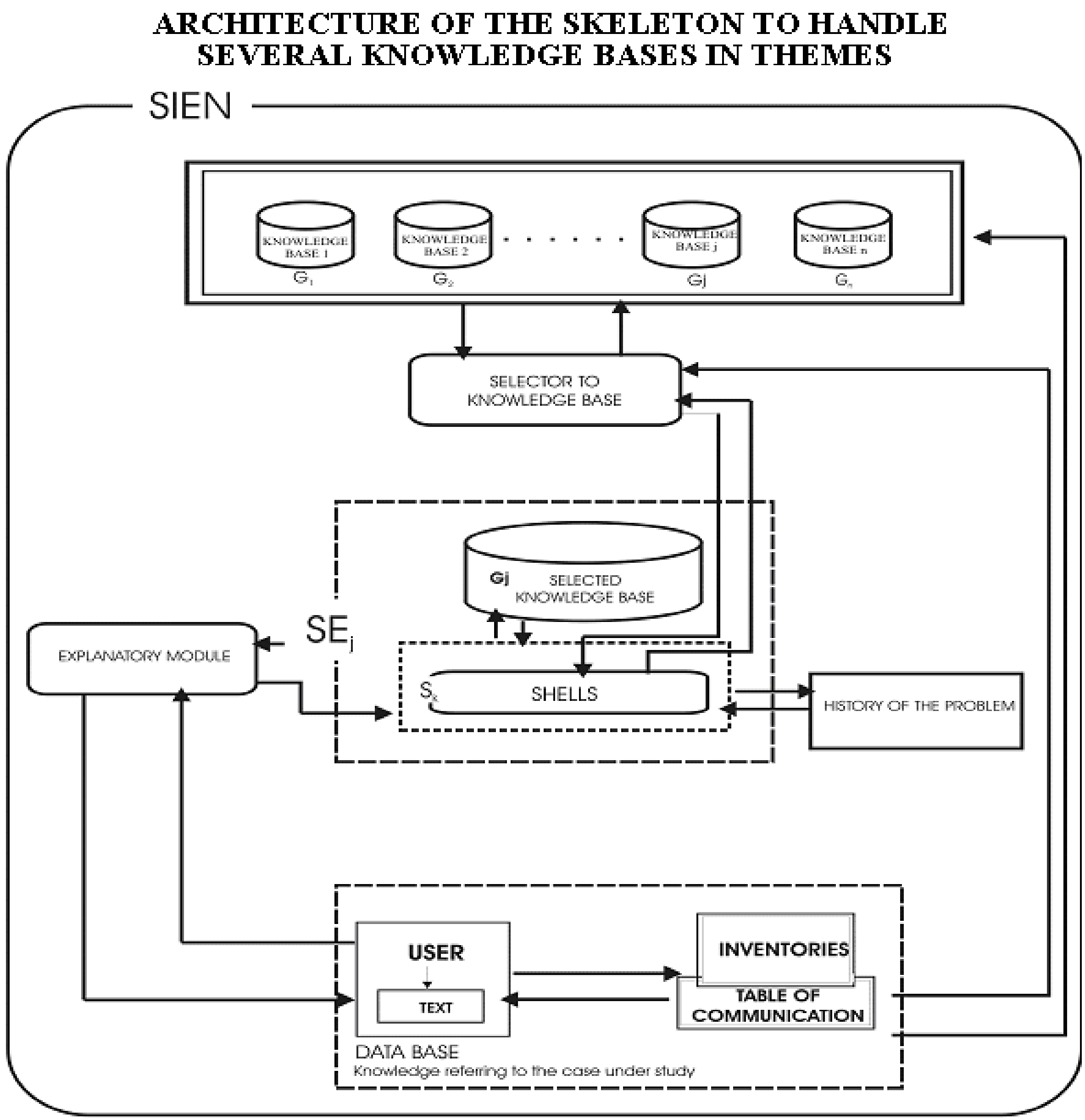

Figure 1. This is the organization of the architecture of the Cooperative Expert System Nodriza(SIEN) that handle several knowledge bases in themes. The ovals represent process, rectangles of dashed lines concern with the permanent data and the rectangles in the continues line are the subsystem

A_1**Error! Bookmark not defined.** $A_2 \wedge ... \wedge A_m \rightarrow B$

being A_1, A_2,... A_m, B, literal that is to say, atomic formulas

Also for each $G_i \subset G$, two parameters $\mathbf{I_i}$ and $\mathbf{FR_i}$ are associated. The first is a directed graph which nodes are **key words** and which arches represent quantities of a value that the human expert assigns to them, this graph was called **inventory**. The second parameter FR_i is a **dynamic relevance factor**, that measures the importance of the KB. The value of the relevance factor is implicitly found in the inventory of the KB. The key words distinguish the bases of knowledge G_i depending on its gender. For example, the word " shock " will indicate in this context that it is a knowledge base related with the suspension.

Goal: A subset $Y=\{G_1,G_2, ..G_k\}$ must be found, such that $Y \subset G$, with $k \leq n$, the elements of Y are potential solutions of the problem given in T. Also with each G_j**Error! Bookmark not defined.**Y a ES_j must be configured. Every deduction of

G_j**Error! Bookmark not defined.Y** will be available in the working common area for all ES's. The communication among the KBs will be made by via transition matrix (communication protocol).

Once the problem defined we should formally follow a strategy for its solution, which consists on identifying the steps to determine the subset $Y \subset G$.

The sequence is: by means of the statement source in natural language, select one or several G_j's of the set G, (or in the event of not counting G as a set of bases of knowledge, then propose an algorithm to divide the combined G in KBs), once done, determine the key words, build each inventory with the key words, identify each element G_j**Error! Bookmark not defined.**G with their corresponding inventory, and finally determine which of the selected Gj's is the most important for that statement using the factor of relevance FR.

If we count with a set of KBs, we begin the selection of the KBs, contrary case, we propose the following algorithm to divide a KB to obtain the set $G = \{G_1, G_2, \ldots G_n\}$.

Division of a Base of Knowledge in Topics

With the purpose of not navigating in big KBs in the search of the solution of a problem, two alternatives are given, the first is to divide the global KB of the whole discourse domain and the second divide the domain and build up a KB for each division. In any of the cases it refers to the KB associated to the domain.

First, suppose the domain is divided and for each division a KB Gj is built, then the Knowledge Base G is the union of all the KBs Gj's of the divisions. A consultation to the global KB **G** involves a communication with some KBs of the divisions.

Being **D** a discourse domain and $D_1, D_2, \ldots, D_n$ divisions of the domain **D**, such $\cup_{i=1}^{n} D_i = D$. If G is the KB of the domain D and G_1 is the KB of D_1, G_2 the KB of D_2, etc, G_n the KB of D_n, then, we say that $G = \cup_{i=1}^{n} G_i$, however it should be clarified that the division of both D and G are not partitions in the mathematical sense, since there is or can be overlaps and therefore it should be established when a division of G is a base of knowledge, therefore, the following definition should be satisfied:

Definition. Being $\mathbf{P = \{P_1, P_2, \ldots, P_n\}}$ a set of problems that can be solved with some knowledge included in a domain D. If D, is a discourse domain and **S**, is an space of solutions for **P** in **D**. We say that **G** is a KB for **P**, if the knowledge **K** of **G** obtained from that domain **D**, is the minimum set or KB minimal with which a solution of **S** is reached for at least a $\mathbf{P_i}$**Error! Bookmark not defined.P,** i=1,2,...,n.

From this point of view, not any division of the global base will be able to be base of knowledge. This is, if $\mathbf{G_j}$ is a division of a KB **G**, and $\mathbf{G_j}$ contains rules of inference $r_1, r_2, \ldots, r_q$, and if $m_1, m_2, \ldots, m_k$ are goals (purpose that is pursued or to be obtained in the base) in the KB **G**, if some of the m_i i=1,..., k, is found in $\mathbf{G_j}$, at least a trajectory (sequence of rules r_i until arriving to the goal) of the r_k with k = 1,..., q can exist, which reaches the m_i i=1,..., k in $\mathbf{G_i}$, where those trajectories that reach m_i i=1,..., k, are solutions of **P**, then we say that $\mathbf{G_i}$ is a KB, contrary case, is not.

It can be that there is more than a trajectory to reach a m_i i=1,..., k, that is, more than a solution, but if the set $\mathbf{G_i}$ contains only a rule, then the set of rules is the minimum and if with it, an m_i i=1,..., k is reached, then $\mathbf{G_i}$ is a KB. Notice that S is the set of all the trajectories that are formed with the r's and that reach the m_k's in $G = \cup_{i=1}^{n} G_i$.

The proposal is to consider that the KBs can be structured in generic parts. The generic parts are composed of rules, which identify a problem of a part of the discourse domain. Here they are denominated ***themes***. This way the themes are relative to each one of the divisions of the domain. Due to this, some elements of the themes will have part in common situated in more than a division, as if the themes were incrusted some with others or also in some cases they behave as strata, these KBs were called KBs stratified in themes. This way, the idea of a KB stratified in themes is to be considered as an encyclopaedia where a consultation can take us to several topics or subtopics. In literature, it is not mentioned or referred to as division of a KB with the name of theme. Some authors like Chandrasekaran (Chandrasekaran, 1984) use the name of generic KB. It is convenient to clarify that a theme is a KB in itself, mainly if it is obtained from a division of the discourse domain. But a theme can also be considered like a sub-base of knowledge when it corresponds to a division of a global KB, the only requirement is that it fulfils the previous definition.

The **key words** are an important mean for the handling of the communication between two KBs, once divided the set **G** in subsets $\mathbf{G_k}$ k=1,2,…. With the key words, we can identify if there is information in common. It is also possible to speak of communication by means of key words that are inside the atoms of the rules q_i involved in the different KBs or fragments.

The communication of the sets G_j can be established by two forms: the first is the human expert considers the communication in an arbitrary form or, as already mentioned, identifying facts or atoms of rules of a KB that are found in another or other KBs; and the second is to apply algorithms divisions to KBs.

It must be insisted that the previous procedure to divide a KB is not unique and there can be more efficient forms in the treatment or construction of KBs with few elements.

The main reason of treating the problem of the division of KBs is centred in the solution of some problems that require of two or more areas of knowledge and that seemingly are aloof. However, great amount of information exists of an area as for another necessary to decide certain cases or to elucidate solutions of the problem in question. Our purpose is to determine how, given two sets of knowledge $\mathbf{G_1}$ and $\mathbf{G_2}$, the common information between both can be identified. To achieve this, we must know what rules or information is in fact in their frontier. This way, if for example we have $\mathbf{G_1}$ and know what intentional information, which can be obtained after the application of a general rule or explicit through the rules in $\mathbf{G_1}$), offers information or knowledge which is in $\mathbf{G_2}$, then we say that the knowledge of $\mathbf{G_1}$ extends to the knowledge of the set $\mathbf{G_2}$, or vice versa, which is relevant. At the end of this section you can see how to determine the dependence of a set with another through these rules.

To solve the problem of the shared information, we think that a finite set of rules that contain the information of both $\mathbf{G_1}$ and $\mathbf{G_2}$ exists. We wonder: How can we find this set?. An alternative to determine clauses of $\mathbf{G_1}$ in the way $\mathbf{A \rightarrow B}$, and clauses of G_2 in the way $\mathbf{B \rightarrow C}$, where B is common in both sets $\mathbf{G_1}$ and $\mathbf{G_2}$. However, it could occur that there is shared information, or considered shared, when the atoms contain key words in spite of not being the same atoms, for example the following two atoms have the same key word, let us say "intestinal", "the patient suffers of intestinal infection" and "the patient was intervened in an intestinal region."

Being $\mathbf{G_1}$ and $\mathbf{G_2}$ sets of clauses of Horn, a strategy to attack the problem could be: that all the antecedents of the elements of $\mathbf{G_1}$ are collected and placed in a set $\mathbf{Q_1}$ and all the consequent ones of $\mathbf{G_2}$ in a set $\mathbf{Q_2}$, verifying if the intersection of $\mathbf{Q_1}$ and $\mathbf{Q_2}$ is empty, if not, then, we have information shared between $\mathbf{G_1}$ and $\mathbf{G_2}$, otherwise they are independent.

The total dependence of $\mathbf{G_1}$ and $\mathbf{G_2}$ is not guaranteed through the rules with the mentioned characteristics. The general rules that can be in $\mathbf{G_1}$ or $\mathbf{G_2}$ should also be taken into account and until after instance them, it is known if information was generated for one of the sets $\mathbf{G_1}$ or $\mathbf{G_2}$.

The information shared in this reference mark, makes us think that it is **incrusted** in a KB contained in another and vice versa. This concept has been called **border on**, that is to say, the set of rules that share information of the two sets G_1 and $\mathbf{G_2}$ (or more, in case there are others KBs), and is defined in the following section. Notice that the **border on** set, is not the intersection of the KBs.

The KB stratified in themes is a KB which consists of themes with the characteristic that one or several rules are incrusted in two or more themes, but these rules are not completely contained, but only partly, that is to say, or an consequent atom or several antecedents are found sharing two KBs. It is mentioned here only a consequent because it refers of Horn clauses.

A KB is composed of themes that can or not have **border on**. To see clearer this concept an example of two sets of rules that form a stratified KB in themes will be used.

The interesting thing of the **border on** concept is that very kindred sets of knowledge can be treated. The idea is to diagnose those sufferings that lead to erroneous topics due to its so similar symptoms direct to incorrect topics or with very low certainty in the diagnosis.

The **border on** establishes kindred knowledge among KBs mainly those of the same area for example, illnesses of the heart and of the lung. Relationships that favour the communication of KBs with processes also exist.

Border on (Friction) among bases of knowledge

In the treatment of shared information, it is of interest to know when two KBs have common elements, and how to identify them. The following definition establishes that a set of rules in which the antecedents or consequent of the rules of the set are in two or more KBs, and has been called **border on**. It should be noticed that if the KBs is structured in inference rules (for example in logic of first order), rules with variables which substitute themselves with the user's facts at the moment of applying the rule could be found, and for that reason it is said in the definition that there could be variables of rules which can be evaluated in a base giving common information as a result in both bases.

Definition. We say that there is a **border on** between G_1 and G_2 KBs, whenever the variables of some of the rules in G_1 are deduced, some variables of the rules in G_2 are evaluated and that as a result of this, common facts are obtained in both KBs. Or some facts of G_1 are also relative to some referred objects of G_1 in G_2.

That is to say, being G_1 and G_2 bases of knowledge structured in inference rules, and Q_1 and Q_2 are defined sets as continues: $\mathbf{Q_1 = \{c_i \mid consequent\ c_i\ of\ q_j\ \varepsilon\ G_1\}}$ is the set of consequent rules in G_1 and $\mathbf{Q_2 = \{a_i \mid antecedent\ a_i\ of\ q_j\ \varepsilon\ G_2\}}$ is the set of antecedents of rules in G_2, then, the **border on** ρ is defined as the set of rules that share or an antecedent or a consequent according to the case, this is:

$$\boldsymbol{\rho = \{q_j \mid A_i\ \varepsilon\ q_i\ y\ A_i\ \varepsilon\ (Q_1 \cap Q_2)\}}$$

With the previous definition the **border on** degree between two or more knowledge bases can be determined. This is, being G_1 and G_2 as before, then the border on degree $\boldsymbol{\rho°}$ is given by the cardinality (CARD) of $\boldsymbol{\rho}$, that is to say, it is the set of rules with the border on (means that knowledge bases friction) property:

$$\boldsymbol{\rho = \mathrm{CARD}(\rho).}$$

Two bases of knowledge (themes) G_1 and G_2 are dependent, if a **border on** degree different from zero exists, otherwise they are independent.

The previous discussion can continue with regard to the **border on** concept. The **border on** allows us to establish a means of communication or dependence of information between two KBs. The dependence or independence (aloof bases) can also be seen by treating the elements of the border on set like restrictions in a database.

From the union of the set $Q = \{q_i \mid c_j$ is a consequent of rules in $G_1\}$ and $R = \{q_i \mid a_j$ is an antecedent of rules in $G_2\}$, a set T that consists of all the rules pointed out by the elements of $Q \cup R$ is found. Notice that the **border on** concept is not exactly the intersection of sets.

The dependence of the KBs will be considered when the set $\rho \neq \varnothing$, but this dependence requires the ideas and concepts of functional dependence of databases, still when this is used only for the application of the equivalence theorem which says: "If F is a set of functional dependences, then an equivalent set of logical propositions G exists, such so that if **f** is a simple dependence and q is a simple logical proposition; then f is a dependence of F if and only if q is a logical consequence of G" (Sagiv, 1981) (Fagin 1982) (Fagin 1983). The algorithm of unitary resolution of Chang (Chang, 1976), can be used to show that functional dependence exists or not.

To establish the communication of the KBs, a matrix C_{ij} was built, where the first column contains the rules that are feasible of communication, the second and the third are the messages that can be direct or indirect, the fourth and fifth contain the KBs transmitting and receiving, after that columns six to seven are flags that light up according to the state of the communication and they indicate: direct communication (FDC) (Flag Direct Communication), indirect communication (FIC) (Flag Indirect Communication), manual communication per user (FUC) (Flag User Communication), communication for another ES (ESC) (Flag Communication by other Expert System), state of the communication system (SCS) (Flag State of Communication System), indicates if there was already communication to avoid cycles (FAC) (Flag Already Communicate), reception acknowledgement, that is to say, the communication (ACK) (Flag the Acknowledgement) was made. The matrix C_{ij} is the Communication Table (CT) Table 1. or the Communication Protocol.

To clarify the communication among KBs, the two KBs G_1 and G_2 must be considered and also their communication table with each one of the elements mentioned previously.

Theme $\mathbf{G_1}$ Theme $\mathbf{G_2}$

R_1 : $A_1 \wedge A_2 \rightarrow A_3$ R_1: B_1**Error! Bookmark not defined.** D_1

R_2 : $A_2 \rightarrow B_1$ R_2: $D_1 \wedge B_1 \rightarrow D_2$

R_3 : $A_3 \wedge B_1 \rightarrow C_1$ R_3: $D_2 \wedge D_3 \rightarrow D_4$

Table 1. Communication Table (CT)

Rules	Message		Transmitting	Receiving	State of the communication System						
	SD	RQ			FDC	FIC	FUC	ESC	SCS	FAC	ACK
$A_2 \rightarrow B_1$	B_1		$<G_1,FR>$	$<G_2,FR>$	1		0	0	ON	0	1
$B_1 \rightarrow D_1$		B_1	$<G_2,FR>$	$<G_1,FR>$		1	0	0	OFF	0	0

It is notorious the fact that once there is communication among KBs, the cooperation among them is feasible. This gives place to define a Cooperative Expert System (CES).

Definition. A Cooperative Expert System (CES) is a system which uses several KBs for a consultation, in such a way that it can establish a cooperation with several of them (or with all) to give a conclusion. Not only does it distribute the information when it is required, but also requests it from whom has it.

The architecture that was mentioned corresponds to that of a CES. Today, the interest of researchers to create a pattern of CES has grown and articles have been published showing different intents to establish this pattern. The consensus up to 1995, assures that most of the researchers treat the cooperation problem using the technology of agents and the architectures of Erman's board (Erman, 1980). Here, an architecture was established which can manage several KBs and configures a ES of first generation with each one of them and has the possibility to share its information at execution time leaving its conclusions in a common area. For such an effect, it uses a communication protocol that consists of a Communication Table (CT) which is established previously, indicating what KBs communicate and what type of message are sent or received. The selection of the KBs, candidates for a particular consultation are made by means of an enunciated source that the user utilises to explain his problem. And from there, which of the chosen KBs that are more important are established, this is made dynamically by means of a Factor of Relevance (FR) which is obtained from the enunciated source.

A Cooperative Expert System behaves a Finite Automata

The architecture of the mentioned CES behaves as a finite automata in the form $<G, M, CT, G_j, K>$ where instead of having a set K of states, there is a set of knowledge bases G, instead of an alphabet Σ, there is a set of messages M, instead of a transition function of states λ, we have a communication protocol (the communication table), instead of an initial state q_0, we have a initial knowledge base G_j for some j of the knowledge bases selected by the enunciated source, and of them, the most important, according to its factor of relevance and finally instead of the set F of final states, we have K like the set of selected KBs, then, we define a cooperative system in the following form:

Definition. A cooperative expert system is a quintuple:

$$<G, M, TC, G_j, K>$$

Where,
G: is the set of KBs.
M: the set of messages that can be sent or required.
CT: is a transition function of KBs, defined as the Communication Table
G_j: the initial KB for a j, is obtained from an enunciated source.
K: is the set of selected KBs.

In this model the obtaining of the initial KB and the function CT present an interesting complexity in their acquisition.

Being $G=\{G_1, G_2,..., G_n\}$ a set of KBs, T an enunciated source in natural language, G_j an initial KB determined by T, really although, with the enunciated T several KBs can be obtained, the relevance factor is the key to select one, which will be the initial KB. Once located in a KB, it will be possible to pass to another KB only if the message requested by the configured ES with the initial KB requests it, otherwise there will not be transition to another KB. It is necessary to mention now that the transition function λ behaves as the CT, since in it the messages as well as the KBs which will visit one another are found here. It is clear that all the KBs that visit one another have a common area from where they are read and deposit the data.

The architecture of this CES has great applications, being of the most important, generating KBs from other KBs, utilising solely enunciated source with which we can choose what is of interest for some KBs. This is another research topic that will be left for the future.

The architecture of the CES which was named SIEN (González, 1991) explained in broad strokes, allows to simulate a good "conversation" and a good cooperation between two or more ESs. The communication among ESs in this architecture is centred in the use of a CT that is built with the human expert's help and that simulates a communication protocol.

With the CT, an effective cooperation among several ESs is established except if the candidates to communicate are pre-established in a registration chart where the name of the KB and its interpreter are registered.

The communication among KBs is not sequential (although there is a list of base candidates for the consultation). It behaves as a hypertext system, that is to say, any ES can interact with other ESs.

Conclusions

The architecture of the CES was defined as a finite automata where the set of states is interpreted as the set of KBs, the set of signs as the set of messages, the function of transition of states as the TC and the initial state, as the j-th KB determined by the user utilising an enunciated source.

The design of the CES architecture is due from the problem solution of dividing a KB in fragments, this leads to the definition of new terms used in this work in the environment of ESs, such as: key words, the definition of **border on** among KBs, the Inventories that distinguish the semantics of the KB, the Relevant Factors FR, the Communication Table TC, Direct Communication, Inverse Communication and finally the communication at execution time.

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