DESIGNING KNOWLEDGE AND EXPERT SYSTEM ENGINEERING

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This communication consists of two parts. The first one deals with the Representation of knowledge and the second one deals with its processing. Here below, I describe the first part by laying down some hypothesis for basic activities of representation of knowledge. It is an integrated view of how a propositional and inter-propositional account of knowledge can be represented considering the proposition as a minimal unit of observation. It is a fragment of methodology related to semantic networks which claims that the information stored in the network, in most cases, is intensional. It is an experimental approach for the representation and the interpretation of knowledge articulated on a finite set of primitive operators ($=$, $\neq$, ω) and based on a finite set of cognitive and language invariants which I postulate as existing primitives of any domain.

1. The research of congnitive and language invariants of the domain

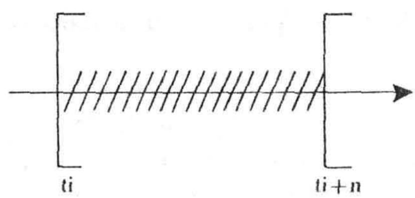
Any predicable (Pred)[1] of a domain (D) endowed with a referential system (R) after getting instantiated a set of properties $P = \{p1, p2, p3...pn\}$ has been effectively filtered by a set of different types of notions $N = \{n1, n2, n3...nk\}$. Indifferent of its modes of conception (for instance, either by classical or logical model: Mereology part of Lesnieswcki or by the topological model — R. Clay, or yet other suitable models). There exists a set of invariants which govern all the laws which constitute those models. Taking into account this fact, here below I have tried to put forward some basic concepts on how to represent and process the "knowledge" and "domain knowledge". It is a fragment of study consisting not on the logical representation of existing relations between the "terms" of an "énoncé" (in the sense of Tarski), neither on the taxonomical analysis based on the behaviouristical aspects, nor on the analysis of nodes and links which allow us to constitute partly the meanings (Semantic networks [1, 19, 20]), but on

[1] Primarily, I suppose that the domain is a set of predicables. Every element of the domain is basically predicable. The dichotomy of any domain in the form of objects and relations is not a primitive operation. The concept "predicable" will be defined down later in details.

the primitive operators which allow any live expert to extract and to constitute a set of cognitive and language invariants which I postulate as existing primitives of any domain knowledge.

2. Link between "Information processing" and "Knowledge processing"

Any processed unit (consequently the process of communication is built up) has got its own material values if and only if it is efficiently and rapidly processed in a simple and clearcut way. To achieve this one has to establish a link between "Information processing" and "Knowledge processing". From the application point of view we found a lot of methods of extracting knowledge (rules) from data. The wellknown method is the algorithm ID3 (J. Ross Quilian) which has been broadly used in the commercial expert systems. On the conceptual level, by processing I mean that it is a set of instant states extracted from the concerning space (information, knowledge, communication...etc.) and represented by a half bound open interval, bound on left and open on right.



Further, if there is a processing in any specified space there will be necessarily a begining in that space and according to its final stage, we can class it into two types.

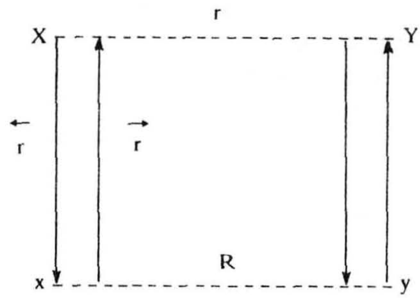
a) Resulting process

b) Non-resulting process

Irrespective of these two types, the notion of "process' contains the following basic concepts (Alain Lecomte [9])

Let X and Y be two general nouns and r be the general relation between them. We have ⟨X r Y⟩ (a general relation "r" linking 2 general nouns). Let x and y be two individuals and R a particular relation. We have ⟨x Ry⟩.

From these two postulates we infer some relations; for instance ⟨X r x⟩, ⟨x r X⟩(a general source relation (r) linking a general noun to an individual and a general goal relation (r) linking an individual to a general noun. More schematically we have:



By using lambda notation, we have:

$$-\lambda\,(X,Y)\ \ (r\ (X,Y))$$
$$-\lambda\,(x,y)\ \ (R\ (x,y))$$
$$-\lambda\,(X,x)\ \ (\overleftarrow{r}\ (X,x))$$
$$-\lambda\,(x,X)\ \ (\overrightarrow{r}\ (x,X))$$

(We mean that the predicate(λ) between the two arguments X and Y is true when and only the relation 'r' or 'R' between X and Y is true)

3. Some basic "reperes" for knowledge structuring

A. Subject matter: Invariant of the discourse

Any proposition (P) of a discourse ($\mathscr{D}$) has got evaluated and interpreted if and only if it has been extracted from the production ($\mathscr{P}$) of the discourse. During the moment of production ($\mathscr{P}$), there are creation of classes of notions and evaluations of certain relations between those classes. Neither those classes, nor those relations which bind them are permanent. Every conceptor of model must take into accout the above factors in the designing phase of a system of representation. Further, if we assume that (P) is an element of ($\mathscr{D}$) it presupposes that P owns a set of observable characteristics and belongs to a set of observable units. As a external observer we are interested here in its epistemological and heuristical aspects. The epistemological aspect of A. I. deals with what kind of facts about the world can formally be represented and the heuristical aspect deals with how those facts can be made available to a finite computational device (Ref. Epistemological problems in artifical intelligence, John McCarthy [13]).

In addition to that, we associate an event (E) to (P) which is an instanciative representation of (E). By using the terminology of Bobrow, we could say that (E) is an element of the "World-state" and (P) is an element of "Knowledge-stage" at an instant-state (ti)(1).

(i.e)

(V)(P) ($P \in \mathscr{D}$) $\rightarrow$ (P owns a set of observable charact) and ($P \in$ to set of obs units)

$$(V)(P) \xrightarrow{\text{associate}} (E)$$

The above primary operation is a part of any intellectual activity. But where do we get (P)?. By answering this question, I join Jean Blaize Grize when he says "Qu'il faut la saisir dans ses productions" (One should catch it from its productions: La Logique moderne Fascicule I & II[3]). This precaution will allow us to extend the classical point of view of A. Church on (P) and on ($\mathscr{D}$) (Introduction to mathematical logic).

I lay down the following hypothesis to start with:

Let($\mathscr{D}$) represent the universe of discourse.

Let DOM = {D1, D2, D3..Dn} a set of domains related to ($\mathscr{D}$)

Let D = {Pred1, Pred2, Pred3..Predn} a set of predicables. We suppose that every element of (D) is predicable.

Let $\begin{Bmatrix} = \\ \neq \\ \omega \end{Bmatrix}$ $\{\epsilon,\ c,\ \epsilon\,\text{loc},\ \varepsilon\}$ be a set of primitive operators.

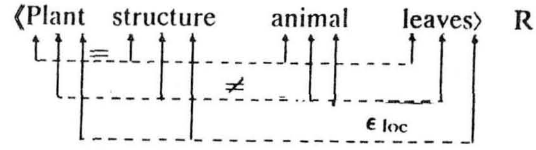
$\mathscr{P}(\text{Pred})_{O=\text{objects}}$

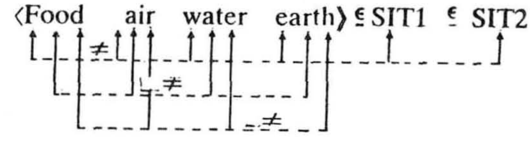
$\mathscr{P}(\text{Pred})_{R=\text{relations}}$

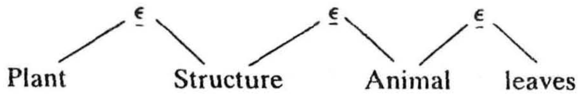
Any unit of (D), by virtue of set of primitive operations, with reference to a given problem related to any domain become "objects" or "relations" of the domain in a particular situation.

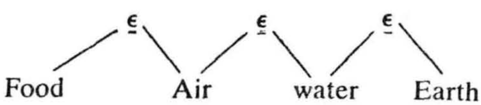
Let me give a partial representation of the concept "plant"(J. Ross Quilian [16]).

The entire frame is built with a compound operator " ϵ ". This operator is









made up of three primitive operators $\{=, \neq, \omega\}$. The operator of differentiation $(\neq)$ includes the set $\{\in, c, \in_{loc}, \varepsilon\}$.

For me, a discourse ($\mathscr{D}$) is not a mere set of propositions but rather an abstract set of products resulted from a set of chained operations accounting the referential framed values designated by the couple (Ψ_0, Ψ_1) where Ψ_0 and Ψ_1 are the participants of the act of the discourse and hence the act of assertion. Practically, all systems of representation of knowledge, irrespective of their basic modes and types (syntactical, logical, semantical) consider that (P) is a static product. For instance, the representational view of D. Bobrow is static and subject(EGO) oriented. The framework representation proposed by him is partial and it does not account for the point of addressee. "Representations are viewed as the result of selective mapping of the aspects of the world" (Dimensions of representations in Representation & Understanding: Studies in Cognitive Science). From this statement, it is not clear, how the selection/mapping of units are first encountered during the modeling phase and secondly how this phase has been integrated in a representative space. Similar to this view, William A. Woods, who in the field of semantic networks first emphasized that some nodes of the net should represent intensions, in (What's in a link: Foundations for Semantic networks[19]) introduces Egolink while identifying the intensional identity. This way of bringing any object of the universe to the EGO-TYPE representation is not sufficient, because I think that the intensional identity is not uniquely subject oriented process (Ref. the section below: The need for intensional & extensional representation). The dynamical aspect of (P) and the point of view of others are almost neglected in the representing process. Taking into account the point of view of others in the frame representation from which deductions are made or whether they are built into the programmational device, I am partly adhering to the position of McCarthy in his new form of reasoning "Circumscription" wherein the goal is achieved by a "Co-operated action". This indeed raises other types of problems that I have discussed in "A formal apporach to intersubjective relations: Shared enunciation" (N. Ganesan[7]) wherein, I have remarked that the "Assertible content" of Frege is shared by the couple (Ψ_0, Ψ_1).

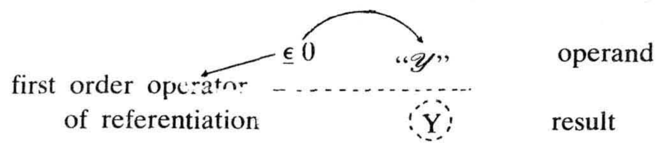
In this context let me join McCarthy while declaring "How to express rules that give the effects and events when they occur concurrently". A system of representation of knowledge indiffferent of its modes of conception must take into account the invariants from aspect, time, spatial relations, modality, number, person, state/process, vision, perception, culture..etc. on its designing and conceptual level and a coprojected view of (Ψ_0, Ψ_1) is necessary in the representing process.

B. The first order operator of referentiation

Most of the wellknown K. R. systems are based on the "Representational Hypothesis" of Brian C. Smith [2]. According to him the main task is to provide the representational enterprise with formal representations of "its own constitutions." This would be possible if we build a process that "knows" about itself and if we subscribe to the view that "Knowing is representational." Advocating the above principle, I am insisting on the aspect of propositional account of knowledge in the sense that I have advanced earlier. Besides, to every process of representation, we associate the first order operator of referentiation which consitutes the point of repere of a predicable. What do we mean by first order operator of referentiation?

How do we consitute it? Is it an indispensable parameter in modelling a system of representation of knowledge? All these questions are to be solved by the designer before entering into the processing phase of the knowledge.

Let $\in 1 \langle (\ )\ x, y \rangle$ be a 3-tuple, where "( ) x" is the object to be modelled and "Y" is the referential point. $\in 1$ is a primitive operator. In a much more abstract stage, if we base on the constitutional level "Y" should be constructed and determined in an earlier stage. Let us say "$\mathscr{Y}$" the primitive stage of the term "Y" before "Y" gets nominated as a referential point to ( )x and before it gets instantiated the referential coordinates. I represent that primitive state by the following diagram:



I consider "$\mathscr{Y}$" as a representant (built-in component) of the intensional properties of any object. A set of primitive operators (Space—Time—Vision) has been advocated on "$\mathscr{Y}$". The result of this primary operation is "Y". $\underline{\epsilon}$ 0 is the first order operator of referentiation which assigns a set of primitives to the operand "$\mathscr{Y}$" and which characterizes the nominal constitution of any object.

C. The need for intensional and extensional representation.

Without entering into the traditional disputes of logical and philosophical concepts about the couples (intension, extension) of Carnap, (denotation, connotation) of Russell, (Sinn, Bedeutung) of Frege, (type, token) of Quilian and (referent, referential value), I want to quote the following, which would be useful to a better comprehension of the process of representation. Strictly on the behavioural context we can say that the the analysis of intension is a scientific procedure and the assignment of an intension is an empirical hypothesis, which like any other language hypothesis that can be tested by observation of language behaviour.

What we find in most of the semantic works that the intension of a predicate (Pre) in a lnanguage (L) for a person (X) at an instant (ti) as the necessary and general condition that an Object (O) ought to possess so that (X) accept to apply (Pre) on (O). In most cases the extension is the strict reverse of intension. I consider that the characteristics like "general and necessary condition" and "Object ought to possess" are built—in components but not as given entities. The above consideration does not account for the point of the addressee. It is based mostly on the analogical analysis. I consider that the intension of a notion (N) in a language (L) for the first party (Ψ_0) and his addressee (Ψ_1) at an instant (ti) in a contextual situation (SIT) endowed with the same referential system (R) is the general built-in condition conceived around the object (O) so that the couple (Ψ_0, Ψ_1) accept to apply (N) to (Pre) and (Pre) to (O). Strictly working either on intensional or extensional aspects create unnecessary problems. To avoid this we will start from a common point and I say that the intension is getting chraracterized if and only if the extension got characterized and conversely.

Most of the semantic networks representation use (ATTRIBUTE, VALUE) pair by means of nodes and links. What is the internal concept of nodes and links? Are they primitives? What do they basically import structural or assertional aspect of an uttereance for which it stands? or both the aspects? On the contrary to general and spreadout opinions on semantic networks, I think that at a primitive stage, it doesn't import anything (neither structural nor assertional) whereas during the activation stage of the net (taking into charge by Ψ_0, Ψ_1) which covers the notion of Trancient -process Account of Quilian as well as the notion of EGO of WOOD, it has to be identified how the fragment of network under question has been taken into charge(assertional or definitional) and how it has been oriented for further interpretation.

Besides, in most of the semantic networks representation, the difference between assertional and structural or definitional links is not fully expressed. It is not clear in the following fragments of representation such as:

— ⟨JOHN EAT APPLE⟩

— JOHN
EAT APPLE (Semantic)

— JOHN $\xrightarrow{\text{EAT}}$ APPLE (Sematic networks)

—EAT (JOHN, APPLE) (LOGIC)
(INST EAT1 EAT—EATABLES) (Slot assertion representation)
(EATER EAT1, JOHN—1)
(EATEN, EAT1 APPLE)

Whether they represent the intensional and conceptual representation of the event "John eating apple" or the assertional fact at an instant (ti) about the act or state of John. The justifications and discussions brought by WOODS are not satisfactory. If it is assertional, how the operation of assertion has been advocated? Does the network account for the manner in which the assertion is carried out in a context? Do we have necessary and sufficient information about? While we represent the event "John eating apple" and while we assert the content of that event do we deny the facts "John not eating a pear"? or "It is John who is eating an apple not Peter."

Any deductible semantic network must account for this in the process of representation.

4. The couple (Object, Relationship): a constructive concept

A. Requirements for designing

At this stage, the representational view concerning the referential point is built up. The next step is to constitute the OBJECT in that referential system by advocating some of the primitives operations underlined by Lesnieswcki. Without entering into details, we can quote some of them.

Let CONS: {Tracing, Extracting Focussing, Determining} be a set of primitive operations. The OBJECT ( )X has to be filtered by the set "CONS". In addition to that, I consider the set {ob1, ob2, ob3..obn} endowed with a referential system as "constructive entities" not as "given entities" as it is the case in most of the systems of representation of knowledge. To understand better this part, let me explain the term "predicable". Does an OBJECT ( )X possess inherently this property? or is it constructive one? Mr. J. P. Descles says that "Un prédicable, entité complexe renvoie à un état nonborné et stable. C'est une propriété intensionnelle non catégorisée ni en nom ni en verbe. Ce prédicable est représentable par un ouvert d'un certain espace topologique" (A predicable a complexe entity refers to a nonbound stable state. It is intensional property which is not categorized neither as nouns nor as verbs neither as objects nor as relations. It can be represented by an open topological space). At a primary level, I suppose that any object inherently possess a virtual property that could be asserted as a predicable; but it does not refer as it was mentioned to a nonbound and stable state but rather refers to a nonbound and unstable state and the intensional property is a built—in component. It comes to some extent of constructing a "state of affairs" (L. AUSTIN).

B. Basic shells for designing

A possible organizational set-up in terms of deductible scenarios from the couple (OBJECT, RELATIONSHIP) of the "World state" to the couple (UNIT, RELATION) of the "Knowledge state", as well as the different phases of modelling & processing the knowledge may be viewed as follows:

( )A

PREDICABLE/CATEGORY SHELL ↕ (Space/Time /ref. point physical desc)

IDENTIFICATION/ASSERTION SHELL ↕ (Ontological properties vision/taking into charge of the entity ( )A.) Actualisation)

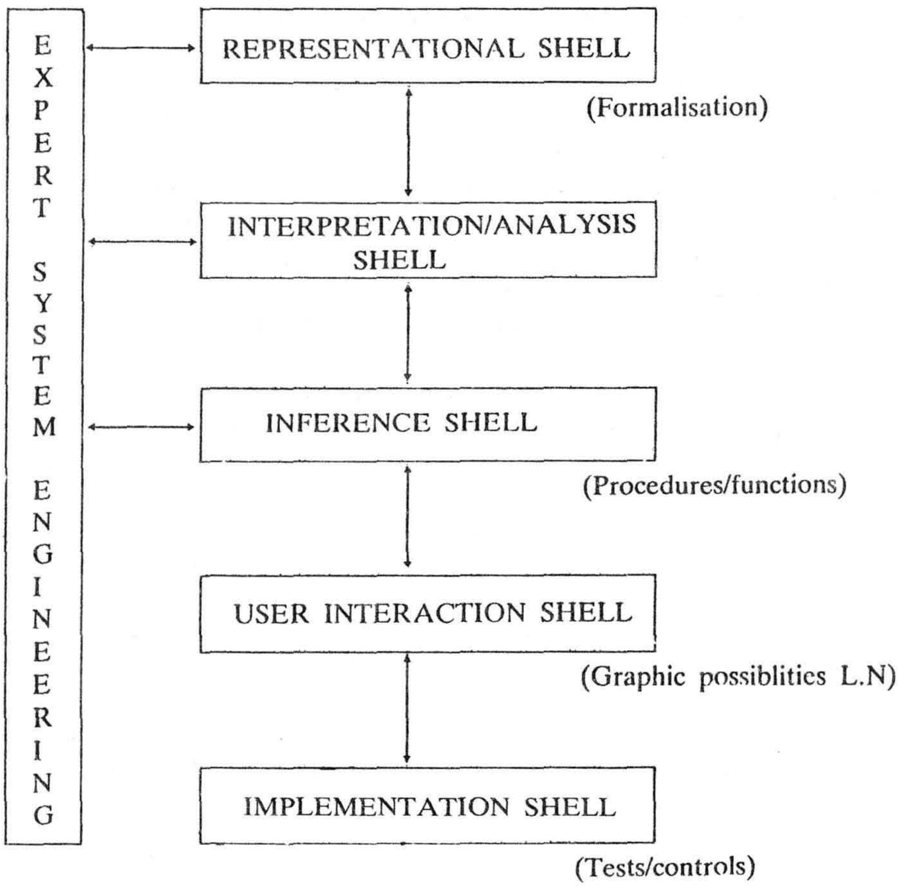
PREDICATIVE SHELL (links & predication)

A comparative view of the classical representational view of Bobrow and (Moore & Newell) to the above fragment model is:

1. DOMAIN KNOWLEDGE → PREDICABLE/CATEGORY SHELL
   REL {(Object, Relationship) unit, Relation)} — IDENTIFICATION/ ASSERTION SHELL
2. OPERATIONAL CORRE-SPONDANCE → PREDICATIVE /REPRESENTATION SHELL
   REL {Action(World state) Represent(knowledge)}
3. PROCESS OF MAPPING (How the knowledge be used in the process of mapping — INTERPRETATIVE SHELL
4. INFERENCE MATCHING — INFERENCE SHELL
5. ACCESS MECHANISMS — USER INTERACTION SHELL

6. SELF AWARENESS

IMPLEMENTATION SHELL CONTROL/TEST.



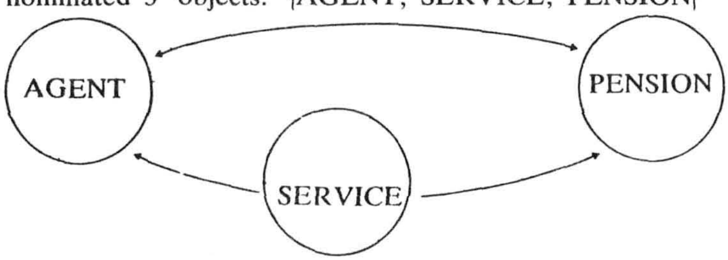
The problem is now putting together all the individual fragment in terms of a coherent high order structure. For instance, if it is possible to represent each fragment by means of a formula(Predicate calculus) or by means of a semantic net(semantic networks) or by yet another suitable models(Lakoff-Type, Fillmore case-representations[5]) the major task is then to interconnect those shells by synthesizing the whole framework by means of primitive operators. When a model is synthesized, any object can be chosen as a part of high order level object connected to it. From the structural point of view the above consideration may be viewed as a componential and functional analysis for describing a model. A pragmatical projection of the above framework on a specified domain provide a model of expertise.

C. Setting the basic relationships around the OBJECT

If our main objective is to conceive some suitable mechanism for representing knowledge, then one of the fundamental issues is in determining its form, its content and finally its organisation (built—in components, primitive terms, cognitive categories, primitive operations) in order to construct the basic principles of that mechanism. Any representational unit of that mechanism must import primitively all the potential indices of the input knowledge. Besides, the cognitive and language invariants used to describe a domain knowledge is in one way context—independant oriented providing a complete analysis of the accumulated knowledge for an active perception and understanding.

The problems discussed above can be integrated in "Requirements Modelling" (world oriented). The "Requirements" models describe relevant aspects of a portion of the world in a context/environment. A fragment of this may progressively be implemented by using a machine oriented models. At this stage we can assume that the specified domain is made up a set of objects OBS: {ob1, ob2, ob3,...obn} which in turn establish a set of Relationships between them.

Let ⟨A R B⟩ be the triplet where A and B are any objects of the set OBS and R be a finite set of possibles RELATIONSHIPS between them and R′ be a finite set of possibles RELATIONS between A and B of the specified domain. Let us consider the following domain knowledge where we have willingly nominated 3 objects: {AGENT, SERVICE, PENSION}



Before going to establish a list of finite set of possible relations on and between those objects of the Domain, let me explain the following.

Let(A); it is an expression that every one of us has been manipulating from the school age. If we want to establish a model of relations around (A), I distinguish two important sets:

I. PRIMITIVE SET
II. PREDICATIVE SET

The first case concerns about the identification level wherein the object (A) can be recognised if and only if it exists the object (A) in the referential domain, not necessarily to be in the domain knowledge. The couple $(A,\bar{A})$ constitutes simultaneously by the mere existence of A. At this level one could identifiy the object(A) by means of a set of differential properties we have already advocated the primitive set of operations "CONS" to designate A. The differentiation ($\neq$) is hence a primitive operator. The couple of primitive operators(IDENTIFICATION, DIFFERENTIATION) is complementary to each other

The second case concerns about the predicative relations wherein the object(A), here the AGENT establishes a set of predicative relations: {r1, r2, r3,...rn} in a predicative situation. Among those predicative relations, we can extract a subset whose strategy is to constitute the kernel node of the model of relations.

a) Associative relations
b) Hypothetical relations
c) Analogical relations
d) Inferable relations

We explain the above set of relations by the following expressions.

Agent(X): X is an agent
Name(X)
Age(X)
Birth-date(X)
Residence(X)
Bachelor(X)
Married(X)
Male(X)
Female(X)

Pension(Y): Y is a pension
Minimum(Y)
Maximum(Y)
Rate(Y)
Month(Y)
Value(Y)
Attribution(Y)

Service(Z): Z is a service
Administration(Z)
Account(Z)
Finance(Z)
Public-rel(Z)
Computer(Z)
etc.

$\text{Human}(X) \Longleftarrow \text{Male}(X) \vee \text{Female}(X)$
(X is human if X is a male or X is a female)

$\text{Have-wife}(X) \Longleftarrow \text{Married}(X) \wedge \text{Male}(X)$
(X has a wife if X is married and X is a male)

$\text{Have-husband}(X) \Longleftarrow \text{Married}(X) \wedge \text{Female}(X)$
(X has a husband if X is married and X is female)

In this predicative situation the set {Age, Name, Birthdate, Residence Male, Female etc.} may be considered as associative relations and the set {Human, Have-wife, Have-husband} may be considered as inferable relations.

5. Modes of Respresentations

A. The operator "TRANS"

One of the major goals of the expert system engineering is to point out how the problem solving strategy can be viewed as a flow of reasoning that goes from a set of evidence to a set of acceptable conclusions. Almost all types of expert system, irrespective of its assigned tasks (Interpretation, Prediction, Diagnosis, Design, Planning Monitoring, Debugging, Instruction, Control etc. ref. Building expert system Frederic Hayes Roth Addison Wesley) have somewhere integrated the above basic skill in their components. The way in which the above strategy is implemented is sometimes different and depends upon the engineering fields. Given a problem, the way in which we are decided to solve it by an Expert system or KBS leads us to scan over the building strategy of an Expert system. How the building task is undertaken depends upon on how we are decided to structure the problem and how we manage to fit the live's expert knowledge into those structures. Broadly speaking, we can say that at the set of mechanisms and techniques used in the field of Knowledge engineering answer mainly to the following question.

At what conditions and on which environments and by what methods any system(S) endowed with a set of observable characteristics {A, B, C..} could be able to execute {X, Y, Z..} ?

The techniques used, embody mainly human knowledge of a particular application area combined with inference mechanisms and control strategies such as data driven or goal dirven which enable the program to use this knowledge in problem solving situations. More precisely, in the tradition of

"Problem solving" (Ref. Simon, Newell, Feigenbaum) we constitute the triplet ⟨Ei, Ef, O⟩ where Ei is a finite set of initial states; Ef is a finite set of final states and O is a finite set of operators. A solution (S) to a problem (P) is a finite set of sequence of application of operators. In other words a solution to a given problem is a complex operator which transforms the set of objects describing the initial situations (INITSIT) into the set of objects describing the final situations (FINSIT).

Let: {OB1, OB2, OB3..OBn} a finite set of objects describing INITSIT.

Let: {ob1, ob2, ob3..obn} a finite set of objects describing FINSIT.

Let: {op1, op2, op3,....opn} a finite set of operators

Let (L) the language used to describe the objects

$$F: \langle OB1, OB2, OB3..OBn\rangle \longrightarrow \langle ob1, ob2..obn\rangle$$

$$OBi \longrightarrow obi = f(OBi) = opi$$

$$i = 1,2,3..n$$

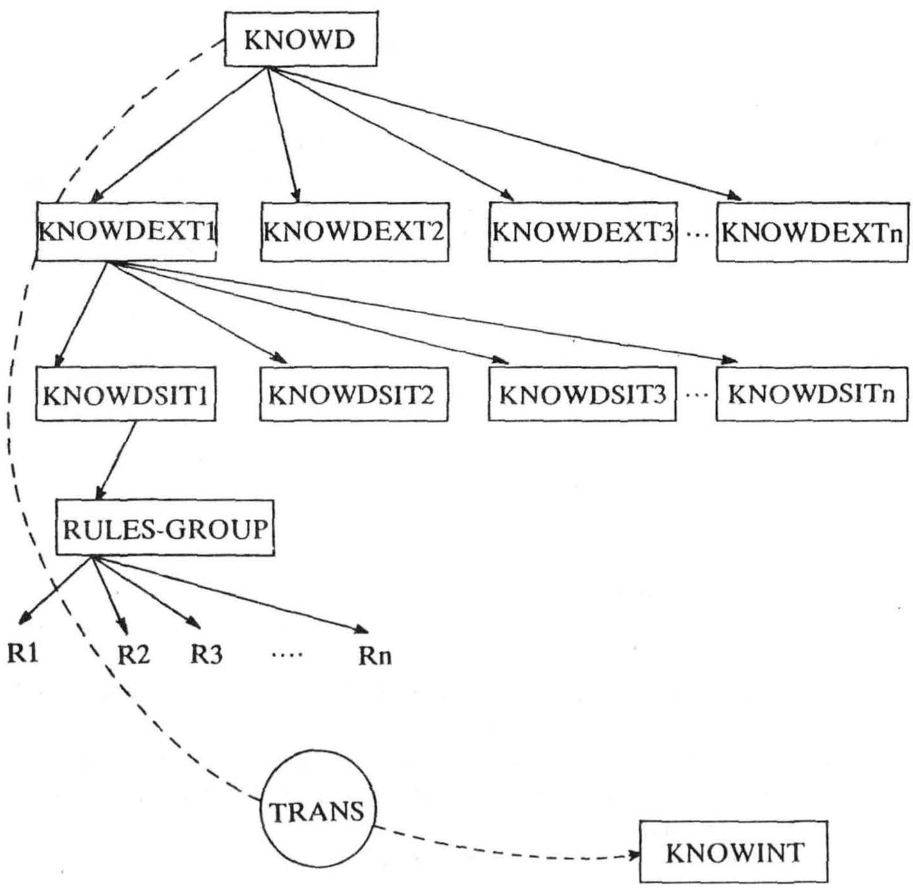
Here, I consider the couple of objects ⟨OBi, obi⟩ as constitutive entities not as "given entities" of a referential system. In most case, the human behaviours merging up from the "Homosapiens" side are representable and programmable. I am using the term "representable" in the sense where the process of transition from external knowledge into an internal knowledge is relatively deductible and calculable, where as those which are merging up from "Homosentiens" do not. Man is able to solve a problem making use of the couple ⟨Acquis, Vecu⟩. Machine could almost do the same if it would be possible to formalize and represent the required knowledge and to endow the machine the necessary skills to make use of that knowledge. I lay down the following set of hypothesis:

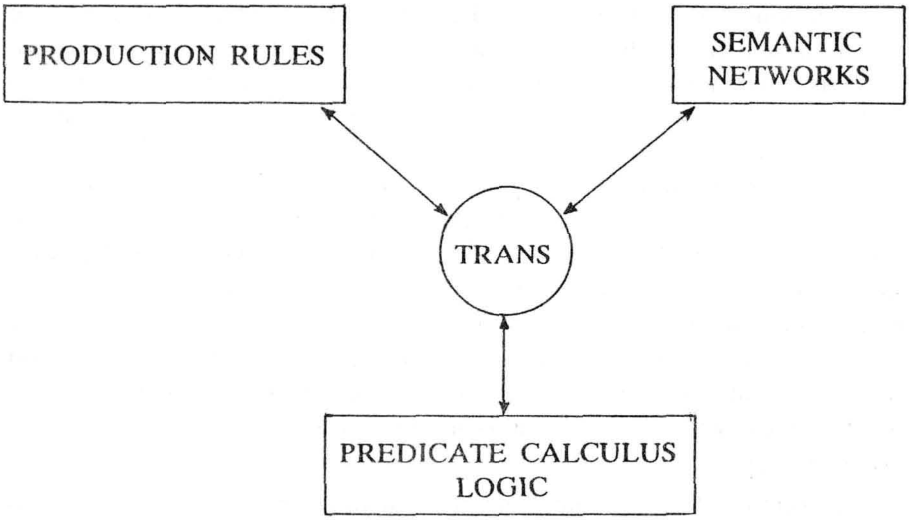
1. Let "TRANS" an unary operator
2. To every unit of knowledge "KNOWD" we associate a finite set of external knowledge "KNOWDEXT".
3. To very "KNOWDEXT" we associate a finite set of situational knowledge "KNOWDSIT"
4. Let "KNOWINT" a variant of "KNOWD" obtained after a sequence of applications of the operator "TRANS"
5. Let {SIT1, SIT2, SIT3..SITn} → ACT1 ∨ ACT2 ∨ ACT3 ∨ ACTn} a set production rules advocated on each "KNOWSIT". The intermediate steps can be expressed as follows:

A. (∀) ( ) TRANS ( ) ----→ (KNOWD)

B. $(\forall)$ (KNOWD) TRANS (KNOWD) $\longrightarrow$
{KNOWDEXT1, KNOWDEXT2..KNOWDEXTn}
C. $(\forall)$ (KNOWDEXT) TRANS (KNOWDEXT) $\longrightarrow$
{KNOWDSIT1, KNOWDSIT2, KNOWDSIT3..KNOWDSITn}
D. $(\forall)$ (KNOWDSIT) TRANS (KNOWDSIT) $\longrightarrow$ KNOWINT.

One of the basic functions of "TRANS" is to transform a "KNOWDEXT" into a "KNOWDINT". How and to what extent would it be possible to carry out this task? This indeed, invariantly depends upon the modes of representation on the strategic controls and on reasonning mechanisms used to configurate the "TRANS".





A representational configuration of "TRANS" may take different forms, for instance it is sequence of applications predicate formulae if the transition uses the predicate calculus or it is an activation set of primitive operators in the case where "TRANS" uses the semantic networks, or else it is a finite set of orderes rules if the transition uses production rules.

B. An appropriate modelling required

The most fundamental contribution so far of Artificial Intelligence and Computer Science to the joint enterprise of Cognitive Science has been the notion of Physical symbol system (i.e.) the concept of a broad class of system capable of having and manipulating symbols, yet realizable in the Physical Universe' (Ref Newell-physical symbol system, Cognitive Science No. 4) Most of the A. I.projects since Dendral till now have, in one way or the other, manipulated the above concept. Newell & Simon define a symbol as physical pattern that can occur as a component of a physical structure, composed of a number of symbols related in some physical way.

Let the quadriplet $\langle S, F, M, R \rangle$ by a physical symbol system, where

$S = \{s2, s3, s4..sn\}$ a finite set of basic symbols manipulated by P. S. S.

$F = \{f1, f2, f3..fn\}$ a finite set of formulae generated from the set S.

Let M be a finite set of symbolic meanings assigned to those formulae and $R = \{r, r2, r4..rn\}$ a finite set of rules applied to F.

This symbolic set-up and the manipulation of symbolic meanings are to some extent applicable in commercial expert systems. Propositional and predicate calculus are such a set up. But the fact, we started manipulating symbols and thereon the appropriate set of symbolic meanings. We are inevitably invited to manipulate symbols in the sense that we advocate herebelow. The above set up, which is primarily sufficient to symbolic reasoning is not adequate enough to human reasoning. Symbols in the sense of Newell are simply a physical core of units which refer to a pre-setup forms. I don't think that he has manipulated a physical pattern (strings of characters) like "PPLAE" and "IVFE" instead of "APPLE and FIVE" respectively. In other words, representations and reasoning based solely on physical and structural aspects of symbols are not adequate, to solve a problem; because every symbol before manipulation has already got an organised social, cultural and referential set up. A representative candidature from those aspects is to be accounted in the representing as well as the reasoning stage.

Using symbols for facts and symbolic reasoning for factual reasoning is an established fact in the knowledge engineering field, which to me, is not simply confined to building expert systems. Knowledge engineering, a complxese area, considered to be a set of principles and mechanisms used to

— Extract
— Categorize
— Formalize
— Interpret
— Make use of

the necessary and sufficient knowledge and the related cognitive invariants, in order to solve skillfully a given problem on a computational device. A prototype system, having the above characteristics is nowadays partially realizable by the Expert system technology assigning basically some of the following skills of an ideal Expert system.

— Expertise skills
— Symbolic reasoning skills
— problem solving skills
— Translation skills
— Cognitive and self identification skills

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