

CONCEPTUAL ANALYSIS AND KNOWLEDGE MANAGEMENT

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Contents

1) Introduction.....	3
2) Some General Remarks Concerning Knowledge Representation	4
3) The Domain of Reference - Knowledge Management	16
4) Knowledge Description and Conceptual Graph Theory.....	18

1) Introduction

There exists an impressive quantity of literature dealing with knowledge representation that covers highly technical contributions as well as more philosophical ones or again those that have a more or less explicit "cognitive" orientation.

So, it is not very astonishing to notice that the definition of what knowledge representation is, is a quite fuzzy one.

It is not our intention to give a historical survey of that notion neither to proceed to a critical enumeration of the several topics that are covered by it.

Our objectif is, rather, to develop a conceptual framework that should permit us to handle the major descriptive problems in the conception of knowledge based systems.

In order to be able to put forth in a systematic way our conception of knowledge representation (KR), we will start in the next section (section 2) with some general remarks concerning the problem of KR. In section 3 we will discuss several aspects of knowledge management that is, following our point of view, the domain of reference of KR. In section 4, we will give a short characterization of knowledge based systems (KBS). In section 5 we will try to isolate several major descriptive problems that are to be solved if we envisage the realization of a KBS. In section 6 we will set up several hypothesis that should be taken into account by conceptual analysis. In section 7, finally, we will sketch out a conceptual theory of description by the means of the conceptual graph theory developed mainly by Sowa (1984).

2) Some General Remarks Concerning Knowledge Representation

The most simple way to get an intuitive idea of what knowledge representation is (or could be), is to ask what we understand by the notions "knowledge" and "representation".

In order to avoid major philosophical investigations of these two notions, let us start with a very simple exemple which has only a didactic value.

Let us assume that we are in the museum of the Louvre, in Paris, and that our attention is caught by a wooden, monochrome statuette of the 14th century, in gothic style, representing Saint Marie holding the crucified Christ in her arms.

Basically, our attention could be satisfied in two ways: either we have "enough informations" about the statuette and we are able to identify it ourselves (given a degree of precision that requires the satisfaction of our attention), or we have not "enough informations" and, in this case, we are constrained to consult an information source that is supposed to be well-informed.

Let us assume, now, that the satisfaction of our attention corresponds to the characterization of the statuette that we have given before ("statuette", "wooden", "monochrome", ...).

If we are able to satisfy, alone, our attention we must, necessarily, possess ("in our head") a kind of model or schema with the following generic features:

SCULPTURE:
PERIOD:
MATERIAL:
CHROMATICS:
DATING:
MOTIF:

It is only by assuming the existence of such a model that allows us to identify the above mentioned statuette:

SCULPTURE: "statuette"
 PERIOD: "gothic"
 MATERIAL: "wood"
 CHROMATICS: "monochrome"
 DATING: "14th century"
 MOTIF: "Saint Marie holding in her arms the crucified Christ".

If we don't have this model "in our head", we have to look for it elsewhere - in other words, we have to consult a source of informations, not any source of informations but a relevant source of informations which is a source that possesses or exhibits exactly that model.

Roughly speaking, the statuette in the Louvre is a *thing* or an *object* which is accessible or interpreted by some "model" that constitute a kind of *vision* or again a kind of *knowledge* of this thing or object.

Now, we have to distinguish between the "model" or the "schema" that exists in the head (or somewhere else) and that enables someone to assert something of an object and the expressive form that we are free to choose in order to represent this model or schema. Indeed, the above written model with its several labels constitutes, properly speaking, the *representation* of a (mental, social, ...) model that gives us a view of an object.

We could have choosen for the labels SCULPTURE, PERIOD, and so on, some arbitrary symbols (for exemple the letters S or P) or again some more perceptively oriented symbols (for exemple a schematic figure instead of the label SCULPTURE or a diamond instead of the label PERIOD). Such changes don't affect at all that what is called generally the descriptive power and adequacy of the model. It affects only *the language of expression* - the *terminology* in a very wide sense - that we use in order to *represent* a described vision or knowledge. Naturally, the use of some verbal or visual language of expression presupposes rules of its usage otherwise the representation of knowledge becomes completely arbitrarily.

There are a lot of hypothesis and theories of what the nature of knowledge is: neurological activity, linguistic activity, psychological activity, purely formal activity, and so on. For the moment, it seems to us, that we

haven't any serious prove in order to choose between those theories or others.

The sole possibility that we have actually is to put forward competing *descriptions* of it and to *test their validity relative to some context* in which knowledge becomes "active" and observable.

Let us come back to the "model" representing a certain vision of the statuette which is exposed in the museum of the Louvre. It is, in its actual form, only a very incomplet outline of all those of someone's activities that we could possibly observe in this given context.

The above outlined model doesn't say nothing, for instance, of the relationships that hold between the several quoted generic features. The identification of these relationships are, nevertheless, an important criterion in the description of knowledge because, in one context, someone could "bring together" the features DATATION and STATUETTE whereas, in another context, he could "bring together" the features DATATION and MOTIF.

So, even if someone ascertains the existence of a set of generic features, he could ascertain, simultaneously, different *configurations* of them. In our exemple, someone ascertains with the triplet DATATION, MOTIF and STATUETTE two configurations: with the first one, he ascertains the temporal location of the statuette (14th century), but with the second one, he ascertains the temporal location of the motif (he ascertains, for instnce, the fact that the motif represented by the statuette exists since the first century of the Christian ere).

The central notion here is the notion of *configuration* that expresses the hypotheses that knowledge is a "structured whole" or again, in a more technical terminology, an intensional entity that could be represented informally, for our exemple, as follows:

SCULPTURE: "statuette"
 is characterized by PERIOD: "gothic"
 is characterized by MATERIAL: "wood"
 is characterized by CHROMATICS: "monochrome"
 is characterized by DATING: "14th century"

is characterized by MOTIF: "Saint Marie holding in her arms the crucified Christ".

The internal structure of this configuration is very simple: it states only the fact that there is one, and only one, generic feature (i.e. SCULPTURE) that is interpreted by a set of other features which are independent from one another (i.e. between which doesn't exist a relationship).

The label "is characterized by" doesn't represent a defined relation. It could be substituted by an arrow or an arbitrary symbol but, again, the substitution of representational figures wouldn't change anything in the meaning of the relation. Intuitively, we prefer to label out the relation between SCULPTURE and PERIOD by the name "is localized by" suggesting by this change that there is a relation of temporal location between these two features. Nevertheless, if we don't have a theory of temporal location or, again, of the relation of characterization, the use of different labels is completely arbitrary and hasn't any consequence for the description of knowledge and its formal treatment.

One of the most difficult problems in knowledge representation is precisely the problem of the definition and of the elaboration of conceptual and formal theories of canonical types of relations we need for the description of knowledge.

Going back to our exemple, let us assume now that we are not entirely satisfied by a response given following the quoted model. We could be unsatisfied, for instance, because the response is too general or because it leaves out several aspects like the identity of the artist who is the creator of the sculpture, the place of its production, its history or again its cultural context.

Those possible reactions to a given response lead us to take into account that a knowledge and therefore also its description is *context-dependent*. There doesn't exist one and only one true and relevant knowledge of something. Knowledge is true and relevant only given a certain context (or "world").

We have, therefore, from a descriptive point of view, to introduce the notion of context that validates a model of a domain of reference. In our terminology, we will speak of a *contextualized configuration*.

As we will see again later on, a contextualized configuration is decomposable in an "outer" configuration that dominates one or more "inner" configurations.

If we assume that there is a description of the statuette like our initial one but that there may exist, simultaneously, other possible descriptions of the same object and that someone could or would like to handle them together (given certain goals of personal or professional satisfaction or something like this) then we have to question us how we can deal with that from a descriptive point of view.

In taking into account, for instance, several textual sources relating something about the statuette under question, one source might give a general description in the spirit of the above outlined model, another source might give a more specific one focussing on, let's say, the motif of the statuette, its history, its symbolic aura or again its relationships with other Christian symbols, a third source might introduce complementary informations "activating" generic features like "authorship" or again "geographic origin" of the statuette, a fourth source might expose in comparison to other sources of information, some controversial informations - it might ascertain, for instance, that the authorship of the statuette isn't an individual but a collective one or, again, that the statuette isn't a statuette of the 14th century but of the beginning 15th century, and so on.

Finally, you can imagine quite easily that there is again an other source of information, a more differentiated and complex one, that handles all the informations exposed, separately, by all those sources of information: it describes the statuette following our generic model; it focusses on, let's say in a special paragraph, the motif of the statuette, introduces then the question of the authorship and the geographic location of the statuette and problematizes, finally, litigious informations like the datation of the statuette or the collective or individual authorship of it.

Our exemple of the different sources of information is, as we think, a quite realistic one that referred to what is called sometimes a context of

multi-expertise, i.e. a context that is characterized by a multiplicity or again a community of experts who deal with an objet or again a situation. In order to take into account such a context, there are several problems to distinguish:

- a) which kind of all these informations should be described,
- b) what are the basic assumptions that underly the informations that we have to describe,
- c) what are the "mecanisms" that permit to derive that informations from the basic assumptions,
- d) among the informations that should be described, which ones could be considered as given or known informations and which ones should be considered as novel or unknown ones.
- e) what is the "nature" of the controversy between the informations that should be described,
- f) how we should lead someone through all these informations in order to enable him to satisfy his objectifs.

Problem (a) refers to question of what is a *representative (relevant) set of knowledge* for a knowledge description; problem (b) to the question of what is the *canonical basis* of a representative set of knowledge; problem (c) to the question of what are the *operations* or again th *rules of formation* we need in order to derive from the canonical basis the whole representative set of knowledge; problem (d) to the question of what of the representative set of knowledge should be introduced as *partially new definitions relying on canonical knowledge and/or derived knowledge*; problem (e) to the question of what of the differences in the representative set of knowledge is in the scope of *conceptual relativity* or in that of *referential relativity* as well as to the question of how to handle *the revision of (a subset of) knowledge*; problem (e), finally, of what is a representative set of *conceptual plan structures*.

We assume that these problems - and those quoted before - constitute at least a subset of major questions in the description and formalization of knowledge or again, as we prefer to say, of *standards of knowledge*. Therefore, we assume, too, that a theory of conceptual description relies heavily on the following central notions for which it has to provide a formal theory:

- (set of) *configuration(s)*,
- *referenced configuration*,

- *canonical configurations and formation rules,*
- *configurational projection,*
- *configurational abstraction and definition,*
- *configurational contextualization,*
- *configurational partitioning (modularization),*
- *configurational deduction (resolution).*

In the last section of this article, we will try to give a rather systematic account to these notions that constitute, following our point of view, the *descriptive model of a knowledge standard*. The appropriate formal theories will be introduced by the means of the conceptual graph theory that furnishes us, at the same time a language of representation (strictu sensu) by the means of which a descriptive model could be expressed and communicated.

Up till now we have introduced several major problems concerning the description of knowledge but we have left out of our discussion the question of the *field or domain of reference of a description*.

Let us come back therefore to our initial model representing some knowledge concerning a statuette in the Louvre in Paris. An open question is here what kind of knowledge this model does exactly represent.

One could ask, for instance, if this model represents a description of the word "statuette" that refers to an identified object (i.e. the statuette in the Louvre) or the visual form "statuette" that is materialized by the identified object or again a kind of topic or thematic vision of the given statuette (and maybe, partially at least, for a whole class of more or less equivalent objects) that could be vehiculated either by a verbal language of expression or a visual one or again by one and only one (written or spoken) document as well as by several documents.

This kind of underdetermination of the correspondancy between our description and its domain of reference leads us to the necessity to postulate a hypothetical structure or organization that seems to characterize the domain of reference. In a more Tarskian or model-theoretic inspired terminology, we have to advance some hypothesis concerning an object (-language) in order to be able to decide on the truth-

conditions or - as Davidson puts it - of the convention T that holds between a given metalanguage or description and the object (-language).

We will call the object of KR by the name *knowledge management* and suggest that it is constituted by three major components:

- the component called "*document*"
- the component called "*context of communication*"
- the component called "*life cycle*" (of the document).

It is out of question to furnish here a more detailed account of the hypothetical structure of knowledge management. Our intention is to present only some general aspects of it and to show the major tasks that conceptual analysis has to realize in the environment of KBS.

In speaking of the component "document" that constitutes one major part of knowledge management, we do not restrict necessarily this notion to its habitual understanding in terms of "written document" or "text". It is well-known that there are a lot of different types of supports and medias by the means of which an information - or, if you want - knowledge is vehiculated and conserved. In this sense, a document can be a spoken one, a visual one, also a gestual one, and it can physically be realized by several supports included the physiological support of human memory.

In this sense, we consider the document in an extremely general sense as a *structured or organized whole of informations or knowledge* that uses one or more expressive or semiotic codes as well as one or more physical supports in order to be able to vehiculate, to store and to maintain its informations or knowledge.

The next question that arises is how we could approach the notion of "document" as a structured whole of informations and knowledge. We put forward the hypothesis that the document is organized in several major levels which are the following ones:

- the thematic level (dealing with the topic or the content of the document);

- the level of the languages of expression (dealing with the "encoding" or "decoding" of a topic by the means of verbal and/or non-verbal languages),
- the level of the formal and physical organization (dealing with the "format" of the document and with the media of expression),
- the level of the support (dealing with the physical realization or existence of the document),
- the level called "meta-document" (dealing with the insertion of a document in the context of communication and in its life-cycle).

In considering especially the thematic level and the level of the languages of expression, there are, from a methodological point of view, two important distinction to draw.

The first one concerns the fact that the topic or again the content of a document (or a class of documents) should not be confused with the linguistic or non-linguistic (visual, ...) expression of it.

In referring again to our exemple of the statuette, there is, one the one hand, some knowledge concerning this object, and on the other hand one or more codes of expression of this knowledge - a linguistic code or a visual code or again a code of gestures that enable us to speak about this knowledge and to communicate about it.

Now, it is clear too, at least since the linguistic researches of Harris as well as Del Hymes and the current represented by him, that there are several more or less well distinguishable sub-languages by the means of which someone can speak about topics referring, for instance, to objects like our statutette.

In this sense, we have to deal with several types and sets of knowledge standards (or "conventions" in the sense of Lewis): one type concerne the set of disponible thematic knowledge standards, another type concerne the set of disponible linguistic knowledge standards or again visual knowledge standards. More generally, every level of the document articulates a certain type of knowledge standards.

The production or again the comprehension of a document must therefore be understood - metaphorically - as a kind of "teamwork" of

specialized competences that work together in order to produce or to understand a document.

From a theoretical as well as from a practical point of view, this vision possesses important consequences because it requires for the construction of KBS not only the coordination of different competences but also a rather special architecture of a KBS which is that one used in distributed artificial intelligence and in multi-agent systems where a "community" of specialized actors cooperate for the solution of a given problem (Bond and alii 1988, Minsky 1988, Gleizes&Glize 1990).

The second important distinction concerns that a document can be approached following a purely thematic perspective or following a textual or discursive approach.

The latter perspective is rather common in text linguistics or semiotics: given one or more documents (viz. a "corpus"), the principal goal is to reconstruct the thematic standards or again - as van Dijk puts it - the semantic macro-structures "behind" them. The major problem here is the identification and stabilization of a thematic standard or a semantic macro-structure. Indeed, the reconstruction of a thematic standard presupposes already a hypothesis or again rich and explicit thematic knowledge so that one can proceed to the identification and stabilization of the sought thematic standard.

In the first perspective, the emphasis is given to the description and modelization of thematic knowledge, no matter if this knowledge is completely or only partially expressed and stored in one, two or *n* physically existing documents.

This approach prevails undoubtedly in actual KBS like, for instance, in expert systems or again in computer assisted tutorial systems. But nothing hinders us to draw a more general definition of knowledge based systems including also other knowledge standards that are relevant in knowledge management. Given this more general definition, expert systems or intelligent tutorial systems are only special cases of KBS like computer assisted text production and translation systems, electronic edition and information retrieval systems.

The lesson we want to hold back is that the two quoted perspectives presuppose one another in the sense that in more

developped KBS for knowledge management the translation of thematic knowledge in a language of expression and the access from linguistic or textual sources to thematic knowledge are as well important as the manipulation of purely thematic or expert-knowledge.

In order to deal with a document, we have to elaborate *descriptions* that refer to the several levels as well as a "*communication protocol*" that permits the interaction of these descriptions for the production or comprehension of a document.

The elaboration of descriptions presupposes some hypothesis on the one hand concerning the canonical structure of the several levels that constitute a document and on the other hand concerning the structure of the descriptive metalanguage itself.

We should consider these hypothesis in an abductive perspective, that is in a perspective of backward and forward motions between some kind of theory of a specific level and its object of reference. In other words, we need hypothesis in order to start a descriptive work but there isn't any guarantee that they are the best ones.

As far as the several levels of a document are concerned, there are especially the level of the formal and physical organization of documents as well as the level of the languages of expression, in particular the natural language system, that has been studied in a rather systematic fashion. A long tradition in descriptive grammar has provided linguistics with a metalinguistic canon that is generally used in natural language analysis. Even if there subsist quite important problems that are often due to a too specific or again to a too particular language-dependent definition of descriptive metaterms, there exists nevertheless a more or general consensus between linguists how to tackle morphological, syntactical and lexic-syntactical questions. Most of the problems are either problems concerning the choice of an appropriate formal theory for linguistic descriptions or problems concerning the limits of the object of reference of linguistics. The last one influence extremely the approach of natural language semantics. There is one extreme version - defended, for instance, by Jackendoff - that natural language semantics is part of a general conceptual semantics, and there is another extreme version - defended by a Whorfian inspired language theory - that outside language

there isn't any semantics at all, or again, in other words, that natural language determines the meaning in general.

We will not enter in this debat. Nevertheless, we think that there are good methodological reasons to limit drastically the object of linguistics and to reserve most of the semantic and pragmatic questions to that what we call here the thematic level of a document.

It is important to distinguish between the problem of accessing or generating thematic knowledge by the means of natural language and the problem of thematic knowledge management itself. A system that should simulate, for instance, political crisis in a given geographical region needs on the one hand extremely rich and developed descriptions of the topic "crisis" that one can find in very different information sources and on the other hand an access to a database of documents where those informations are stored as well as at least a natural-language like communication system with the user. The first problem could not be handled by superficial descriptions of prominent lexical items that refer to peculiar situations characterizing the evolution of a crisis as it is often suggested by the use of very general (and often extremely loosely defined) metaterms like ACTION, STATE, INTENTION, PLAN, and so on. But, given well-elaborated subcategorization frames of lexical items and the existence of a syntactical parser, such a "semantic" characterization is rather sufficient for the access of reelevant informations in a textual database.

Let us consider, too, the objective of the creation of *virtual documents*. It is well-known that several industrial and technological sectors are extremely "gourmand" in the quantity of their production of documents. So, the idea is to developp, instead of producing a hugh amount of physically existing documents, a big KB containing a set of classes of generic librairies where each one represents some relevant piece of information or knowledge of a domain of reference. Given the particularity of the request of a potential user, one or more librairies will be activated and, by the means of a text-production system, the user will obtain a "personnalized" document that communicates him the wanted informations. Here again, it is out of question to undertake the constitution of such librairies by the means of linguistic theories or methods. In order to developp a general architecture of such librairies and the thematic configurations that are represented by them, we have to appeal to

By the notion of "conceptual level" we encompass not only the knowledge and reasoning abilities of a system but also its abilities to evolve in changing contexts and to establish appropriated forms of communication with the user.

As we will see again, the conceptual level of KBSs has to be distinguished from the material level (the electronic, optronic, ... support), the functional level (the software components) and the computational level (the programming environment) of a KBS.

In choosing a life-cycle perspective for the conception and realisation of KBSs, the main problems with which KR has to deal could be decomposed in three principal phases:

- the phase of the *elicitation of knowledge* from a given corpus of information sources;
- the phase of the *description, the formalization and the representation (strictu sensu) of knowledge*;
- the phase of the *communication of knowledge and the interaction between the system and the user*.

Conceptual analysis as a general methodology of the conception and realisation of the conceptual level of KBSs has to elaborate a motivated framework that is adapted to the principal requirements that determine each phase.

In this article we will deal mostly with problems that characterize that second phase of the life-cycle of a conceptual level in a KBS.

3) The Domain of Reference - Knowledge Management

Let us take the very practical exemple of the specification, conception and realization of a system that should assist people in the plannification of their sojourn in a geographical region like the Ile de France, a region that is localized around Paris. Roughly speaking, the realization of such a system presupposes:

- the description of what you can find in this region,
- the description of the requirements and preferences of a potential visitor,
- the description of the temporal structure of a sojourn and
- the description of some prominent discours strategies as, for exemple, the act of information concerning the relevant objects in the region or again the act of negociation concerning incompatibilities between several requirements and between given requirements and sources that are disponible in the region.

These descriptions constitute together a *conceptual model* of the *plannification of a sojourn in Ile de France by a visitor with the help of a specialized agent*. The empirical quality of the system and its practical interest depends entirely upon the conceptual model.

In order to be able to elaborate such a conceptual model, we need informations or, as we say in our terminology, *documents* that speak of the region, the requirements and preferences of a visitor, the temporal structure of a sojourn as well as of the strategies of information and negociation.

Naturally, we haven't the intention to collect any document but only those that are relevant to our purpose, viz. the realization of a system that assists people in the plannification of a sojourn in Ile de France. In other words, the relevancy of a document depends upon what we call the *context of communication*.

Finally, after having determined the "nature" of a relevant document give our purpose, we will find, probably a lot of written or oral sources that corresponds quite exactly to what we search. Nevertheless there could also be

4) Knowledge Description and Conceptual Graph Theory

Following Sowa (1984:73), a conceptual graph is a finite and connected graph which possess two kinds of entities: concepts and conceptual relations.

"Every conceptual relation has one or more arcs, each of which must be linked to some concept. If a relation has n arcs, it is said to be n -adic, and its arcs are labeled 1,2, ..., n . The term *monadic* is synonymous with 1-adic, *dyadic* with 2-adic, and *triadic* with 3-adic. A single concept by itself may form a conceptual graph, but every arc of every conceptual relation must be linked to some concept".

Conceptual graphs are based on the mathematical theory of graphs (Leszner 1980) that define a graph G

1) as consisting of:

- a nonempty set E of edges or points,
- a nonempty set A of arcs and

2) where the following conditions must hold:

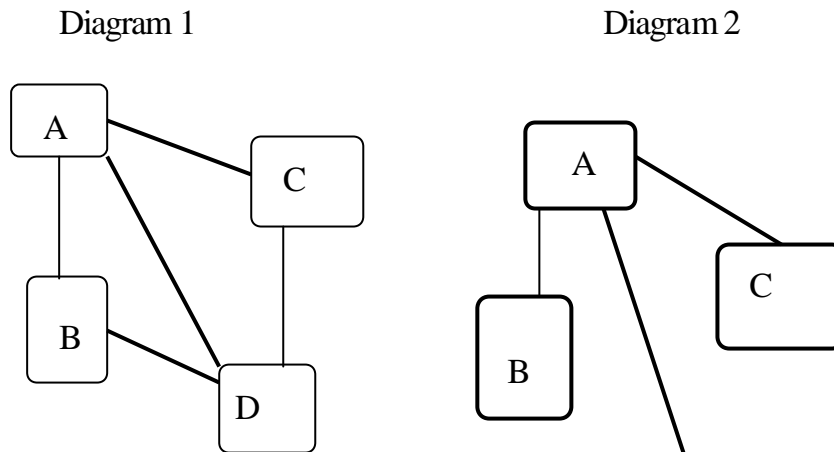
- every arc must be linked to two (not necessarily different) edges,
- no "cutpoints" between two different arcs or again no point in

which one arc cuts itself are allowed to exist.

In conceptual graphs, the edges or points are called concepts whereas a conceptual relation may be either one arc or again the product of two or n arcs.

Normally, a graph is represented by diagrams - a representation form the goes back at least to Euler, the inventor of topology and the

mathematical theory of graphs. For instance, diagram (1) is a graph whereas diagram (2) isn't a graph following the definition given above:

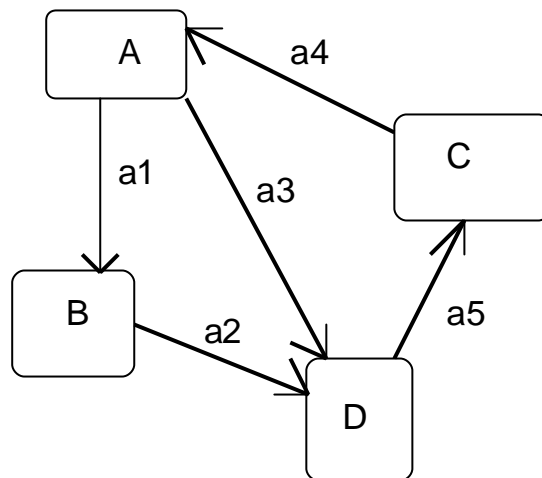


In diagram (1) all arcs are linked to edges whereas in diagram (2) there is one arc that hasn't an edge as its cutpoint.

Notice that the diagrammatical representation is only a convenient tool that enables us to visualize abstract mathematical or logical entities and to speak about them in spatial and perceptive terms (for instance, in terms like "path", "walk", "loop", "endpoint" or again "tree", "leaf", "root", and so on). All these terms, if they are used in a non-metaphorical sense, rely on precise formal definitions.

The graph represented by diagram 1 is called a *undirected graph* because the arcs which are linked to its nodes don't possess any defined direction. Therefore, one could "walk" from A to B as well as from B to A without any difference, viz. without any consequences as far as the direction of the walk is concerned.

Directed graphs, contrarily, possess arcs that possess, diagrammatically, an arrowhead which indicates the direction that one has to follow in order to walk through a graph. Consider the revisited diagram 1:



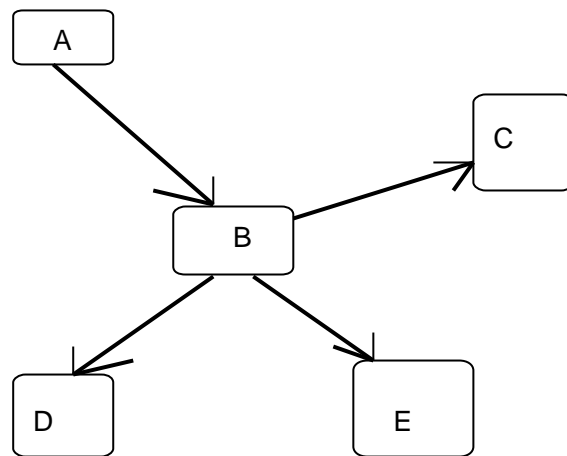
In this graph, one can walk from A to B or again from A to D, but it is forbidden to walk from B to A or again from D to A.

Directed graphs are on the basis of formal tools like transition networks or again augmented transition networks as used in artificial intelligence or again computational linguistics (Nilsson 1980, Allen 1982, Gadzdar&Mellish 1989).

Even if we will not develop here in a more detailed form several aspects of the mathematical theory of graphs, let us note at least an interesting propriety of the revisited graph represented by the diagram 1. This graph possesses an internal structure that allows someone to start his walk at some point or edge and to come back to it after having passed by several other points or edges, cf.:

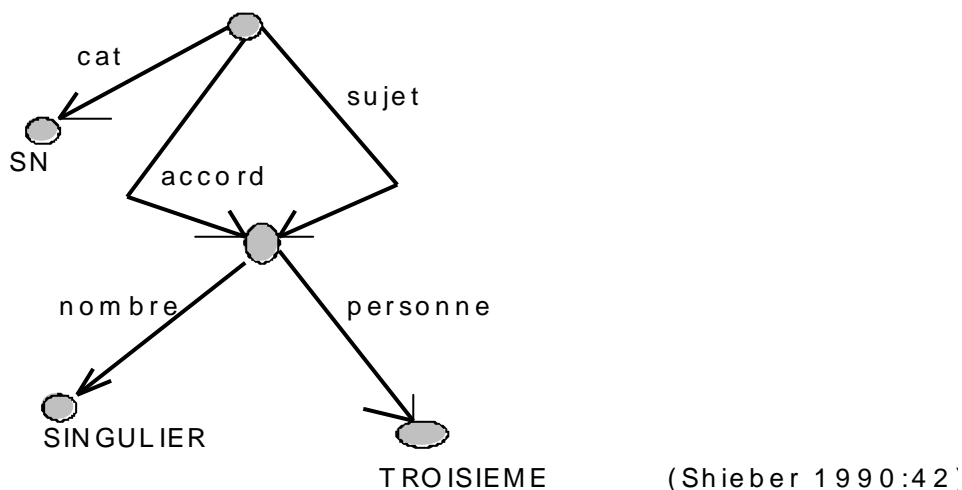
$$A \rightarrow a1 \rightarrow B \rightarrow a2 \rightarrow D \rightarrow a5 \rightarrow C \rightarrow a4 \rightarrow A$$

A graph that possesses such a structure is called a *directed cyclic graph*. A more constrained formal type of graphs is the type of *directed acyclic graphs*, that is a graph where don't exist cycles. Consider, for this, the following diagram:



In this graph, one can walk from A to B, from B to D, from B to E or again from B to C. But there isn't any possibility to come back to the source-point of the walk.

We quote this formal type of graphs because it is frequently used in the context of unification grammar (GPSG, FUG, DCG, ...) in computational linguistics (cf. Shieber 1990). For instance, a structural description for a noun phrase in the third person singular in the subject-position could be represented as follows:



In this formalism, the features ("cat", "nombre", "personne", ...) are translated as arcs whereas the values of a feature are translated as

nodes. The root itself and non-terminal nodes don't receive a special label-name.

As we will see again, the conceptual graph theory of Sowa encompasses directed cyclic as well as acyclic graphs and belongs therefore to the same class of formal theories as the quoted theories used in computational linguistics.

In the above quoted definition of conceptual graphs, there is mentioned the assumption that conceptual graphs are connected. By this property we assume the fact that there exists a possible path (directed or undirected) between any two nodes of a graph. Consider, for this, the two diagrams:

Diagram 1

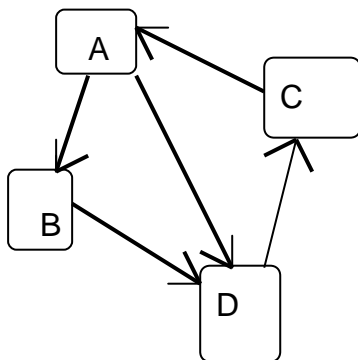


Diagram 2

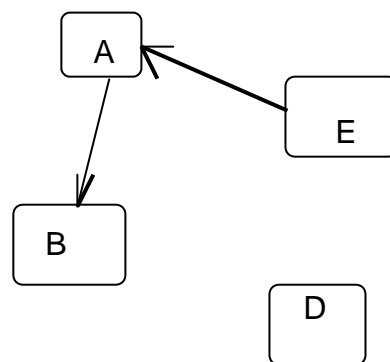


Diagram 1 represents a connected bipartite graph. Diagram 2 shows two disconnected graphs: the graph $\{A,B,C\}$ and the graph $\{D\}$. In cutting the directed arcs between on the one hand A,B,C and on the other hand D it is impossible to find again a path between the four nodes. Note also that in cutting D from A,B, and C, the graph $\{A,B,C\}$ becomes a directed acyclic graph which possesses a unique path between its nodes (sometimes such a directed acyclic graph is called a tree).

In conceptual graphs, the nodes or edges represent the concept-types and the arcs the conceptual relations. A conceptual graph may be represented as a diagram (see figure 1) or in a linear form (see figure 2):

Figure 1:

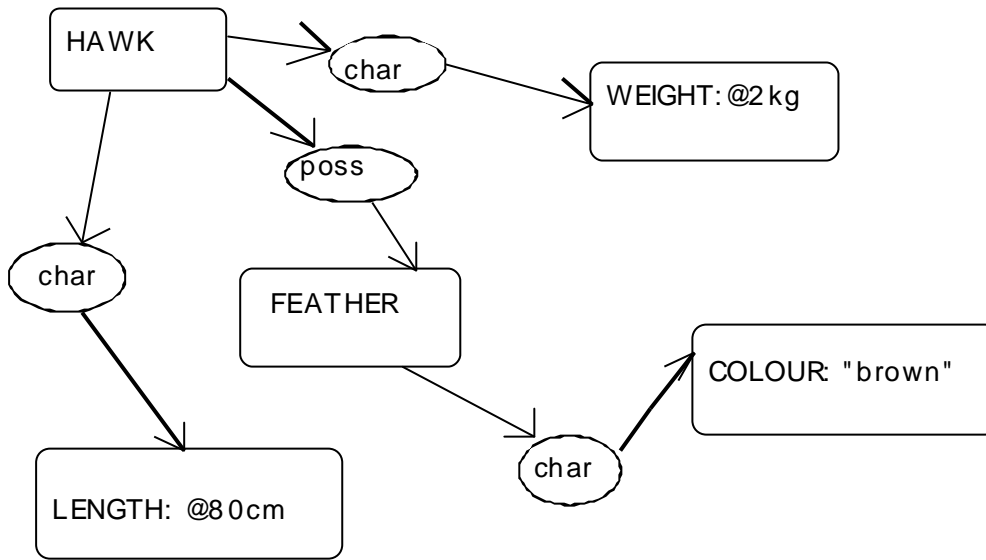


Figure 2:

```
[HAWK] -
(char)---> [LENGTH: @80cm]
(char)---> [WEIGHT: @2kg]
(poss)---> [FEATHER] -
          (char)---> [COLOUR: "brown"].
```

Figure 1 and figure 2 show the same conceptual graph representing a very simple thematic configuration that defines a hawk by its length, its weight, and by the colour of its feathers.

Concept-types are represented either by boxes or by square brackets whereas conceptual relations are represented by circles or rounded parentheses.

The domain or field of concept-types visualized by a box or square brackets is divided in two parts - a left one and a right one - that are separated by a colon:

$$[\quad : \quad]$$

The left part receives the generic concepts or concept-types whereas the right one houses the referents or again the range of values that can satisfy a generic concept or concept-type.

As we will see again, there exists a special function - the function of instantiation - which possesses two arguments from the sets "concept" and "referent" and whose range is the set of truth values {true, false}.

Conceptual relations are always oriented. The direction of a particular conceptual relation is indicated by an arrowhead.

By the introduction of conceptual relations, the set of concept-types that are recovered by a conceptual graph, is divided in ordered pairs of concepts whose elements are a concept belonging to the set of source-concepts and a concept belonging to the set of goal concepts. In this sense, a conceptual relation is a function that determines if an ordered pair of concepts is true or false, viz. if an ordered pair of concepts $\langle x, y \rangle$ is or is not an arc in the graph g .

Even if most of the commonly used conceptual relations can be defined as functions with two arguments, this limitation is not an intrinsic one: conceptual relations can also be defined over three, ... n -arguments.

We will see again later on that conceptual relations can be defined by several general mathematical properties.

In the linear transcription of a conceptual graph as shown in figure 2, we have to chose some concept or relation to be the head. In figure 2 the head is the concept [HAWK]. If we had chosen the concept color as the head, the linear transcription of the graph would be the following one:

```
[COLOUR: "brown"] -
  (char)<--- [FEATHER] -
    (poss)<---[HAWK] -
      (char)---> [LENGTH: @80cm]
```

(char)---> [WEIGHT: @2kg].

This graph represents a thematic description defining something like this: the colour "brown" is a characteristic of the feathers that possess a hawk who has as other characteristics a length of 80 cm and a weight of 2kg.

See again the following linear transcription of the same graph:

[WEIGHT: @2kg] -
 (char)<--- [HAWK] -
 (poss) ---> [FEATHER] -
 (char)---> [Colour: "brown"],
 (char)---> [LENGTH: 80cm].

This graph represents a thematic description defining the fact that the weight of 2kg is a characteristics of the hawk who possesses feathers that have as characteristics the colour "brown", and who has also as a characteristics a length of 80 cm.

An interesting feature of the linear transcription of a conceptual graph is the fact that it exhibits necessarily a certain view point - a certain concept - from which the graph or the represented description are defined. Even if the truth-values of a description are not submitted to changes, they allow nevertheless different point of views from which it could be seen or understood. So, there is a kind of underdetermination between the truth of a description and its (subjective or pragmatic) "apprehension" following a kind of principle of relevancy. But the (subjective or pragmatic) "apprehension" of a description following a kind of principle of relevancy presupposes necessarily the possibility to evaluate the truth-values of a description otherwise we wouldn't be able to decide if we deal with several point od views of a same description or if we deal, contrarily, with different descriptions.

Let us come back now to the descriptive categorie "configuration". We know already, that from a canonical point of view, a (thematic, linguistic, visual, ...) configuration can be interpreted as a structured whole that consists of a (not necessarily finite) set of dimensions and functions that introduce some kind of order between dimensions.

In this sense there is a strong equivalence between a structural configurational description and the formal structure of conceptual graphs that enables us to translate directly a given descriptive metalanguage in the format of conceptual graphs: configurational dimensions map to the set of concept-types, referential values of configurational dimensions map to the set of instances or values and thematic functions map to the set of conceptual relations.

To the thematic description of a statuette in the Louvre:

SCULPTURE: "statuette"

is characterized by PERIOD: "gothic"

is characterized by MATERIAL: "wood"

is characterized by CHROMATICS: "monochrome"

is characterized by DATING: "14th century"

is characterized by MOTIF: "Saint Marie holding in her arms the crucified Christ".

corresponds the following conceptual graph:

[SCULPTURE: "statuette"] -

(char)<---[PERIOD: "gothic"]

(char)<---[MATERIAL: "wood"]

(char)<---[CHROMATICS: "monochrome"]

(char)<---[DATING: "14th century"]

(char)<---[MOTIF: " Saint Marie holding in her arms the crucified Christ"]].

The equivalency between a configurational descriptive metalanguage and the representation system of conceptual graphs is not only interesting for purely representational objectives, i.e. for the search of an adequate artificial and well-defined language that expresses a description, but also - and maybe much more - because of the fact that conceptual graphs have an explicit mathematical or formal background.

In introducing the theory of conceptual graphs, we have given a more set-oriented and functional account of graphs. Sowa has also shown that conceptual graphs can be translated or mapped - with the help of the operator (function) Φ - into the first order predicate calculus.

"If u is any conceptual graph, then Fu is a formula determined by the following construction:

- * If u contains k generic concepts, assign a distinct variable symbol x_1, x_2, \dots, x_k to each one.
- * For each concept c of u , let $identifier(c)$ be the variable assigned to c if c is generic or $referent(c)$ if c is individual.
- * Represent each concept c as a monadic predicate whose name is the same as $type(c)$ and whose argument is $identifier(c)$.
- * Represent each n -adic conceptual relation r of u as an n -adic predicate whose name is the same as $type(r)$. For each i from 1 to n , let the i th argument of the predicate be the identifier of the concept linked to the i th arc of r .
- * Then Φu has a *quantifier prefix* $\$x_1, \$x_2, \dots, \$x_k$ and a *body* consisting of the conjunction of all the predicates for the concepts and conceptual relations of u . (Sowa 1984: 86).

Let us see by the means of the conceptual graph representing the thematic description of the statuette how this mapping process works:

- * there are six concepts, all of them are individual concepts that possess a specified value;
 - * each individual concept maps to a monadic predicate:
 - SCULPTURE (statuette)
 - PERIODE (gothic)
 - MATERIAL (wood)
 - CHROMATISM (monochrome)
 - DATING (14th_century)
 - MOTIF (saint_marie_holding_in_her_arms_the_crucified_christ)
- * there are five conceptual relations that map to five dyadic predicates:
 - CHAR (statuette, gothic)
 - CHAR (statuette, wood)
 - CHAR (statuette, monochrome)
 - CHAR (statuette, 14th_century)
 - CHAR (statuette, saint_marie_holding_in_her_arms_the_crucified_christ)
- * the six monadic and the five dyadic predicates constitute together the body u of Φ that doesn't possess, in our case quantifier prefixes given the fact that all our monadic predicates have in their argument position $referent(c)$, viz. a constant:

(SCULPTURE (statuette) \wedge CHAR (statuette, gothic) \wedge PERIODE (gothic) \wedge CHAR (statuette, wood) \wedge MATERIAL (wood) \wedge CHAR (statuette, monochrome) \wedge CHROMATISM (monochrome) \wedge CHAR (statuette, 14th_century) \wedge DATING (14th century) \wedge CHAR (statuette, saint-mary_holding_the_crucified_christ_in_her_arms) \wedge MOTIF (saint_mary_holding_in_her_arms_the_crucified_christ)).

In the example concerning some characteristic features of a hawk, there are two generic concepts ([HAWK] and [FEATHER]). Mapped into a logical formula, the graph representing that description looks like this:

$\exists x \exists y$ (HAWK(x) \wedge CHAR(x,80cm) \wedge LENGTH(80cm) \wedge CHAR(x,2kg) \wedge WEIGHT(2kg) \wedge POSSESS(x,y) \wedge FEATHER (y) \wedge CHAR (y, brown) \wedge COLOUR (brown)).

The possibility to map a configural descriptive metalanguage into the representation system of conceptual graphs and the possibility to map conceptual graphs in logical formulae has several important consequences for knowledge representation (latu sensu).

1) They show that there could exist a strong equivalency between description, representation and formalization or, again, between, a descriptive metalanguage, a representational or expressive metalanguage and a formal metalanguage. In other words: even if we adopt a structural or, again, a pragmatic point of view in (thematic, linguistic, ...) knowledge description, it is not - as it has been often argued - in contradiction with formal or logical oriented theories of knowledge representation. What is, contrarily, important here, is the assumption that the formalization of a knowledge-object applies to a description or schematization of such a knowledge-object and not to the object itself. What you formalize is not the object itself but a theory of the object. In this sense, it should be intuitively clear too, that representational and formal tools like (augmented) transition networks or dags (i.e. directed acyclic graphs) which are commonly used in computational linguistics rely heavily on the descriptive quality of the linguistic theory they use in order to analyze (to understand and to generate) linguistic knowledge. Like conceptual graphs, they could be mapped into logical formulae. It is not so much logics - even standard logics - that is questionable here but much more the descriptive quality of theories of a domain of reference. The principal condition in order to compute a description is that it must exhibit a configurational or structural organization.

2) There has been a lot of critics against semantic or conceptual networks concerning especially the notion of "semantics" itself as it is used in those approaches. As it has been argued, semantic and conceptual networks seem rather to describe syntactic structures of labels or figures which have a meaning only for us because we can intuitively interpret them on the background of theories or conventions to which they are referred by ourselves but which are not integrated explicitly in semantic or conceptual networks. There is only in logics where you can find an explicit theory of semantics given mainly in terms of interpretation and evaluation functions that map formulae to models or "worlds" in which they receive truth-values. Conceptual graph theory incorporates a model-theoretic component. As Sowa has pointed it out, one of the most simple way to imagine an abstract model in which formulae have to be evaluated is a relational database. A query behaves like the projection of a conceptual graph or its corresponding logical formula onto the model of the relational database and the evaluation of that graph in the given model by the means of a special denotation operator (or function) δ (for further explications see Sowa (1984: 161-173).

3) From an implementational point of view, the possibility to map conceptual graphs in logical formulae possesses a great interest because it assures their almost direct use in form of structured objects, terms or clauses in logical programming languages. Nevertheless, the implementation of conceptual graphs is not bounded to languages like PROLOG - it is only a historical conjuncture that has put them together.

As we have already seen, (thematic) configurations should not be understood as simple one-dimensional schemas but much more in terms of compounded modules (which are, themselves, configurations) that possess a more or less high degree of generality or specificity and which could be (at least partially) instanciated by some values in a given domain of reference.

So, one of the most important questions is, how to define the constructional principles and rules that govern a (thematic) configuration. In interpreting a (thematic) configuration in terms of a conceptual graph or, again, in terms of a set of conceptual graphs, we will now discuss in a more formal way some basic constructional principles which are developed in Sowa (1984). We will discuss quite briefly:

- the theory of partial ordering of configurational dimensions and functions that are mapped to concept-types or conceptual relations,
- the individuation or instantiation of concept-types and, finally,
- the recursive or inductive definition of a configuration that is mapped to a set of conceptual graphs by the means of canonical graphs, formation rules and the condition of closure.

Configurational dimensions that are mapped to concept-types are defined, in the theory of conceptual graphs, by the means of partially ordered type hierarchies.

From a formal point of view, a partially ordered type hierarchy of three given dimensions s , t , and u relies on the following assumptions:

"1) If $s \leq t$, then s is called a subtype of t ; and t is called a supertype of s , written $t \geq s$.

2) If $s \leq t$ and $s \neq t$, then s is called a proper subtype of t , written $s < t$; and t is called a proper supertype of s , written $t > s$.

3) If s is a subtype of t and a subtype of u ($s \leq t$ and $s \leq u$), then s is called a common subtype of t and u .

4) If s is a supertype of t and a supertype of u ($s \geq t$ and $s \geq u$), then s is called a common supertype of t and u . (Sowa 1984: 80)".

The theory of partially ordered hierarchies is based on some fundamental mathematical properties of relations as, for instance, the reflexivity, irreflexivity, symmetry, asymmetry, antisymmetry and transitivity. The partial ordering, in this sense, is a binary relation that is reflexive, antisymmetric as well as transitive.

The well-known relation "is-a", generally used in artificial intelligence and knowledge representation in order to formalize type hierarchies with (multiple) inheritance of properties from supertypes to subtypes, is a special case of partially ordered hierarchies which are defined as lattices.

In a very elementary way, a lattice possesses an infimum (a greatest lower bound) of two types s and t which is defined by their intersection ($u \leq s \cap t$) and a supremum (a least upper bound) which is defined by their union ($u \geq s \cup t$). Sowa calls the infimum the "maximal

common subtype" of the types s and t and the supremum the "minimal common supertype" of s and t (Sowa: 1984: 82).

For exemple, given a certain description, the supremum of both lexical units "terrestrial vehicle" and "shipping vehicle" is "vehicle"; its infimum is "amphibious vehicle".

In knowledge representation, we assume, furthermore, that all lattices are bounded, even if this is not necessarily true from a purely mathematical point of view. A bounded lattice L possesses a so-called universal type T ("at the top" of a lattice) and a so-called absurd type \perp ("at the bottom" of a lattice) and for any type t in L the condition $T \geq t \geq \perp$ is true.

As Sowa has pointed it out, the definition of a lattice L by the means of intersection and union of types in L , shows a strong similarity with the definitions of relations between sets. So, a set-theoretical interpretation of a lattice defines the universal type T as the universal set Σ of all subsets with the subset relation \subseteq as the partially ordered hierarchy-relation and the absurd type \perp as the empty set $\{\}$.

The theory of partially ordered type hierarchies, set theoretically interpreted, not only can account for the formalism of directed acyclic graphs as used in computational linguistics (see above, figure xxx) but makes also clearer the implicit formal theories that are handled by the most prominent lexicological relations as, for instance, the relation of synonymy, (gradual or categorial) antonymy, hyponymy and hyperonymy or again presupposition (complementarity).

Let us assume Σ , $\{\}$ and \subseteq as well as three concepts or "features" x , y , and z , x belonging to the set S (i.e.: $\{x \mid x \in S\}$), y belonging to the set T $\{y \mid y \in T\}$ and z belonging to the set U $\{z \mid z \in U\}$.

Hyponymy and hyperonymy describe nothing else than a (partially ordered) relation between x in S and y in T with x as the proper supertype of y and y as the proper subtype of x .

Gradual antonymy (or, as Greimas called it, contrarity) depicts a relation between x in S and y in T in a lattice constrained by Σ , $\{\}$ and \subseteq that have either a supremum z in U (defined by their - possible - union) or an infimum z in U (defined by their - possible - intersection) or both.

Categorial antonymy (the relation of contradiction, in the sense of Greimas) depicts a relation of pure difference between x and y (i.e.: $\{y \mid y \in T \text{ and } y \notin S\}$ and $\{x \mid x \in S \text{ and } x \notin T\}$).

(Unilateral) Presupposition or complementarity depicts a relation of complementation where x belongs to the universal set Σ but not to the set S (i.e.: $\{x \mid x \in \Sigma \text{ and not } x \in S\}$).

The famous semiotic square of Greimas describes, in this sense, a bounded lattice defined by the formal theory of partially ordered hierarchies. Neither the sometimes rather metaphoric descriptions of Greimas' model nor its unbelievable arbitrary trivialization in so-called applied semiotics should efface the fact that it is probably the first model in (lexical and textual) semantics that requires - on a purely descriptive or conceptual level - the formal theory of lattices for the description of linguistic and non-linguistic knowledge.

Given a configurational description represented by a (set of) conceptual graph(s), the theory of partially ordered hierarchies permits several basic operations on dimensions in that configuration as, for instance, the specification of (a set of) dimension(s), the generalization of (a set of) dimension(s), the copy of (a set of) dimensions which is a central operation in the construction in the derivation of conceptual graphs, as well as the evaluation of the proximity or again the approximation of two given dimensions in a given configuration.

In other words, the theory of partially ordered hierarchies allows to perform explicitly several fundamental types of operations not only on description of thematic knowledge but also on descriptions of linguistic or non-linguistic (visual, ...) knowledge or again on descriptions concerning more specially the level of the structural organization of a document.

The often discussed problem of the lexical access in psycholinguistics or again the relationship of association between a given term and several other terms in information and documentation sciences are, for instance, only two special cases of the approximation of (sets of) (thematic, lexical, ...) dimensions in a lattice of a given configuration. The major problem here is how to construct an explicit and empirically

appropriate description in which the approximation between (sets of) dimensions takes place.

Conceptual relations representing configurational functions of a given description can also be handled by the formal theory of partially ordered hierarchies. In assuming "at the top" of a lattice some general relation, it is possible to define more specific conceptual relations where the condition holds that a type of relation r is of the same type of relation s if r and s share exactly the same number of arcs.

In thematic as well as in lexico-semantic knowledge representation, there are some major types of relations that are, frequently, used: casual or actantial relations, spatio-temporal relations as well as relations of quantification and qualification.

Casual or actantial relations position configurational dimensions with respect to their functional roles they play in an activity, action or process. Spatio-temporal relations localize configurational dimensions with respect to roles they play in space and time. Relations of quantification and qualification determine ways of existence of configurational dimensions by "secondary" dimensions that play the role of "quantifiers" or "qualifiers".

Given such a rudimentary "ontology" of configurational functions, there are two possible strategies to use it in knowledge representation.

The first one consist in determining a very small set of "canonical" configurational functions which is used indifferently for all particular configurational organizations that may structure a descriptive model. For instance, in the set of actantial relations, there may be defined a relation of "agentivity" describing the fact that one configurational dimension is at the source of the existence of an other configurational dimension, no matter if the first configurational dimension is animate or inanimate, if it is characterizable by an intentional or teleological (goal-oriented) force, and no matter if the second configurational dimension describes a (physical or mental) process, a generic activity or again an action. A greater importance is given, here, to a more systematic description of configurational dimensions as well as to the operations of configurational abstraction and contextualization.

The second strategy consist, contrarily, in the definition of subsets of more specialized configurational functions that constrain, indeed, more or less strongly the identity of configurational dimensions to which they apply.

The casual function of "causality" could be, in this sense, dissociated into a function of "causality stricto sensu", a function of "non-intentional agentivity", a function of "intentional agentivity" or again a function of "teleological agentivity" with theoretical stipulations like the following - partial - ones: "causality stricto sensu" requires an inanimate physical or abstract entity as the causing configurational dimension; "non-intentional agentivity" requires an animate entity as a configurational dimension that doesn't control the causing of another configurational dimension; "intentional agentivity" requires an animate entity as a configurational dimension that controls the causing of another configurational dimension but - contrarily to the function of "teleological agentivity" - without its insertion in a goal-oriented plan structure.

In the same way, it is possible to define a given primitive function of localisation in space and time in more and more specified relations taking into account the dimensionality of space and time, their topology or again their relativity with respect to the position and orientation of configurational dimensions.

This second strategy which is, from a structural and morpho-dynamic point of view, more adequat than the first one, assumes the hypothesis that the "gestalt" of a configuration is much more the result of the interactions of configurational functions than a mere assemblage of independently existing entities via some relations. So, from a descriptive and conceptual point of view, a large amount of work consists in the isolation and definition of configurational functions that constrain and motivate configurational patterns.

In any case, the more and more specified configurational functions can be introduced in a partially ordered hierarchy of types of relations. But there exists also the possibility to introduce them progressively via the operation of the definition of new relations of which the meaning (the theoretical stipulation) is ascertained by an entire (set of) graph(s) representing the configurational constraints which must imperatively be satisfied if a given function applies.

This second way of defining configurational functions represented by conceptual relations seems much more appropriate at least for those configurational functions like the three types of agentivity quoted above that are composed functions and that exercise rather strong global constraints on the structural organization of whole types of configurations.

As we have already seen it, a (thematic, linguistic, ...) configuration is to interpret more likely as a structural organisation unit that is composed not only by some given or assumed dimensions and relations but also by dimensions which define themselves condensed configurations as well as by functions which define - like in general or linguistic morphology - structural constraints for (some parts of a) given configuration.

For instance, one could handle, in a given context of application, the dimension [BIRD] as a "primitive" or non decomposed dimension. But in an other context, the same dimension [BIRD] could be used as the label of a condensed configuration that describes some particular properties of it. The same holds also for the dimension of [FEATHER] which could but must not be a non decomposed dimension. Sometimes, there doesn't exist the need to give more detailed informations of the feathers of a bird, but sometimes it is necessary to - metaphorically speaking - "open the box" [FEATHER] in order to be able to distinguish between different types of feathers, to localize them, to give a more appropriate characterization of such or such type of feathers as, for instance, their lengths, their colour, their morphology or again their essential functions in the life and activities of a bird. In this sense, one will distinguish between types of feathers like the tectrix, the remex, the rectrix or again the down with their special localization on the body of a bird, their particular colours, their length and their essential functions.

Or, let us take again the description of action-types and plan structures as, for instance, of the evolution of a crisis in some geographical region. As Schank and Abelson (1976) have already argued, there are several levels of description and knowledge representation.

There is a first rather general level where one introduces only non-specified plan structures and basic actions like the obtaining of something what is claimed at the beginning of a crisis and some condensed proposition-like descriptions that labels out several interaction-patterns

like BARGAIN, THREATEN, PHYSICAL-CONTROL, and so on which are instrumental actions with respect to the basic action OBTAIN(x) where the variable x stands for the claimed object.

On a second level the condensed interaction patterns receive a general definition and the plan motivating OBTAIN(x) would be organized in some major plan-structures. Like in structural analysis of folk tales, the named interaction pattern PHYSICAL-CONTROL could be decomposed in a serie of typical actions like ATTACK, OCCUPY, COUNTER-ATTACK, DEFEAT, and so on. To each action type will be associated a typical description containing the most prominent action roles, the object of the action, a localization grid or again a slot for instruments that are used. Concerning the more refined description of the plan motivating the basic action OBTAIN(x), it will be dissociated in several "named plans" (Schank&Aberlson 1976) accounting for the fact that the evolution of a crises could be resolved by purely discursive and political means as bargaining, by military means, by means of arbitrations by a third party, and so on. Note, nevertheless, that it is not necessary to give a complet account of all possible interaction patterns and named plans - this is even not possible because of the essentially "open" historical nature of the described object "crisis". As we will see again, there are at least two strategies in conceptual graph theory - type definition and schematic definition of contextualized configurations - that allow to complet or to modify a given knowledge description.

On a third (fourth, ...) level the described interaction patterns as well as the named plans would receive even more detailed descriptions. For instance, the interaction patterns could be decomposed in a serie of state-descriptions that succeed one another or that are combined by more constraining relations like those that define counterfactual patterns, conditional patterns or again probability patterns. On that level, it would be also possible to define several variants of a typical interaction pattern.

The both exemples of the description of the notion "feather" of a bird and of the notion "crisis", even if they refer not only to very different but also to objects that vary strongly in their internal complexity, reintroduce the major problems of knowledge description that we have already quoted at the beginning of our article.

These several levels and components of the description of an object form - informally speaking - a huge and complex thematic

configuration composed by a certain number of sets of more or less general or specific thematic configurations that are referenced to parts of the described object. In other words, they raise the first problem in the elaboration of a descriptive model of a knowledge standard which is the *representative set(s) of* - in our case - *thematic configurations*.

An object not only recovers quite different types of referents but it can be also described, as we have already mentioned it, following several levels of relevancy as well as by several point of views. Nevertheless, the term "object" is generally used for the designation of the "world" that is submitted to an conceptual (thematic, linguistic, ...) analysis and so we use this term, too. The problem of referential complexity and relativity introduces, in any case, a another major problem in the elaboration od a descriptive model of a knowledge standard which is the that of the *referenced configurations* or again that of the instanciation of a configuration.

As we have already argued, it is rather impossible, impracticable and from an operational point of view even undesirable to enumerate the whole representative set(s) of (thematic) configuration(s). We have much more to look for the rules that permit us to generate such a representative set of configurations, to introduce new informations in a given set of configurations as well as to conform a given set of configurations to a certain point of view or context. If we want to elaborate a descriptive model of a knowledge standard that is conform to these requirements, we have to deal with the problems of *canonical configurations* in a representative set of configurations and the *formation rules* by the means of which we can derive all configurations in the representative set, of the rules of the *configurational projection, abstraction* and *definition* that accounts for the introduction of new informations in a given set of configurations and of the *operation of the contextualization* of a set of configurations by the means of which the descriptive model accounts for a given point of view. All these questions could be brought together under the head of *configurational partitioning or modularization*.

Finally, the major task of a descriptive model of a knowledge standard is to fullfill or to satisfy a given set of goals or objectifs like the comparision of an object with other, more or less similar objects, the explication of the internal structure and behaviour of a given (class of) objects, the simulation of possible evolutions of a given (class of) objects,

and so on. To satisfy such goals, requires that we are able to elaborate a theory of *configurational deduction (resolution)*.

In order to start a more systematic investigation of these problems which we have to resolve in describing a knowledge standard, let us assume the following small and rather simple set of conceptual graphs:

1) [BIRD] <---(char)--- [COLOUR]

(char)--- [WEIGHT: @*]

(char)--- [SIZE: @*]

2) [BIRD] <---(part_of)--- [BODY_PART]

(char)--- [SHAPE]

3) [FEATHER:{*}] <---(loc)--- [BODY_PART]

(char)--- [COLOUR]

4) [BIRD] <---(is_a) --- [LARUS]

(is_a)--- [STERNA]

5) [LARUS] <---(is_a)--- [COMMON_GULL]

(is_a)--- [GLAUCOUS_GULL]

6) [STERNA] <---(is_a)--- [SANDWICH_TERN]

(is_a)--- [ARTIC_TERN]

7) [BODY_PART] <---(is_a)--- [HEAD]

(is_a)--- [BODY]

(is_a)--- [WING: {*}@2]

(is_a)--- [TAIL]

(is_a)--- [LEG: {*} @2]

These seven graphs constitute what is called a canonical basis or again a set of canonical thematic configurations.

The first graph stipulates that a bird is characterisable by its (general) colour, its weight and its size. The second graph asserts that a bird is "composed" by body-parts that are characterisable by a shape. The third graph asserts that the feathers are localized by a body-part and that they are characterisable by a colour. The fourth graph assumes that the both species "larus" and "sterna" are birds. The fifth graph assumes that the common gull and the glaucous gull belong to the species "larus" whereas the sixth graph assumes that the artic tern and the sandwich tern belong to the species "sterna". The seventh graph asserts that the head, the body, the tail as well as the two wings and legs are body-parts.

The seven graphs decompose quite simple and general descriptions of several physical aspects of birds as one can meet them in non-specialized guide-books of the world of birds. From an empirical point of view, the canonical basis is not at all exhaustive. It takes into account, for instance, two species of birds, it speaks in a quite general sense of the body-parts and the colouration of feathers, and so on. This fact doesn't represent an inconvenience because, as we have already confirmed it and as we will see a little bit later on, new informations or more pertinent informations could be introduced in the canonical basis, as derived graphs or again by the means of (context-dependent) definitions.

The important point here is that the canonical basis introduces explicit constraints that have to be respected if some graph representing a thematic configuration could be interpreted in or with the help of the set of configurations that are derivable from the given canonical basis. In this sense a graph representing a description like this one:

[BIRD]<---(char)---[METAL]

(char)---[SIZE]

would be rejected or, more precisely, wouldn't be interpreted as a well-formed graph given the fact that there doesn't exist in the canonical basis

some information that stipulates that a bird is characterisable by the dimension "metal". Like in generative grammar, canonical graphs impose *selectional constraints* which permit to distinguish between arbitrary (but maybe form a purely syntactic point of view well-formed) and meaningful graphs.

From a pragmatic point of view, the canonical basis of graphs introduces some fundamental assumptions concerning the *level relevancy* of a description given a context of application. In this sense, a canonical basis can change from one context of application to another. The formal problem is here, how to handle these changes - a problem which claims a theory of epistemic revision in the sense of Gardenfors (1987) or again in the context of a game-theoretical semantics (Hintikka&Kulas 1985).

There exists *four canonical formation rules* for deriving some conceptual graph *g* from one, two or *n* conceptual graphs which are themselves either canonical graphs or already derived graphs:

- 1) the *rule of copy*: a conceptual graph *u* is identical with a graph *w*
- 2) the *rule of restriction*: "for any concept *c* in [graph] *u*, type(*c*) may be replaced by a subtype; if *c* is generic, its referent may be changed to an individual marker. These changes are permitted only if referent(*c*) conforms to type(*c*) before and after the change" (Sowa 1984:94)
- 3) the *rule of join*: "if a concept *c* in [graph] *u* is identical to a concept *d* in [graph] *v*, then let [graph] *w* be the graph obtained by deleting *d* and linking to *c* all arcs of conceptual relations that had been linked to *d*" (Sowa 1984:94);
- 4) the *rule of simplification*: "if conceptual relations *r* and *s* in the graph *u* are duplicates, then one of them may be deleted from [graph] *u* together with all its arcs"(Sowa 1984:94).

The rule of copy plays a central role in the generalization of the description of an object represented by a graph which is defined by the operation of the projection (cf. infra).

The rule of restriction may, given its definition, apply to the restriction of concept-types:

[BIRD] ===(is restricted to)===> [STERNA],

to the instantiation of a generic concept-type:

[ARTIC_TERN: x] ===(is restricted to)====> [ARTIC_TERN: "leslie"],
as well as to both simultaneously:

[BIRD:x] ===(is restricted to)====> [STERNA] ===(is restricted to)====> [ARTIC_TERN] ===(is restricted to)====> [ARTIC_TERN: "leslie"].

The rule of restriction is defined by the theory of partially ordered type hierarchies as well as by the operation of conformation between a generic concept and its referent.

The most important rule is the rule of join that permits the concatenation of two or more (canonical or derived) graphs in order to produce a new graph. Let us take the first two canonical graphs:

1) [BIRD] <---(char)--- [COLOUR]

(char)--- [WEIGHT: @*]

(char)--- [SIZE: @*]

2) [BIRD] <---(part_of)--- [BODY_PART]

(char)--- [SHAPE]

By applying the rule of join to the concept [BIRD] that appears in both graphs, we obtain a new derived graph w:

[BIRD] <---(char)--- [COLOUR]

(char)--- [WEIGHT: @*]

(char)--- [SIZE: @*]

(part_of)--- [BODY_PART]

(char)--- [SHAPE]

This new graph stipulates something like this: a bird is characterisable by its colour, its weight, its size and it is "composed" by body-parts that are characterizable by its shape.

The graph w is quite easily derivable from the canonical basis. But in combining the different formation rules, we could derive much more interesting graphs representing configurations that are rather appropriate to the description of physical aspects of some particular sub-species of birds or again to some concret specimen of a given sub-species. Let us consider the following graph w :

```
[ARTIC_TERN: "leslie"] <---(char)--- [COLOUR: "white"]

      (char)--- [WEIGHT: "12p"]

      (char)--- [SIZE: "80cm"]

      (poss)--- [WING: {*}@2]<---(char)---[SHAPE]

              (loc)---> [FEATHER]

                      (char)--- [COLOUR: "white_and_blue"]

      (poss)--- [TAIL]<---(char)---[SHAPE]

              (loc)---> [FEATHER]

                      (char)--- [COLOUR: "white"]
```

This graph asserts that there is an artic tern with the name leslie, that leslie is a white bird, that it weighs 12 pounds, that it has a size of 80 cm, that the feathers of its wings are white and blue, that the feathers of its tail are white and the shapes of its wings and its tail remain specified.

Now let us look how we can derive this conceptual graph from the canonical basis.

1) The process of derivation leading from the first, fourth and sixth canonical graph g_1 , g_4 , and g_6 to the graph r :

```
g1: [BIRD] <---(char)--- [COLOUR]

      (char)--- [WEIGHT: @*]
```

```

(char)--- [SIZE:@*]

g4 [BIRD] <---(is_a) --- [LARUS]

      (is_a)--- [STERNA]

g6 [STERNA] <---(is_a)--- [SANDWICH_TERN]

      (is_a)--- [ARTIC_TERN]

r: [ARTIC_TERN: "leslie"] <---(char)--- [COLOUR: "white"]

      (char)--- [WEIGHT: "12p"]

      (char)--- [SIZE: "80cm"]

```

requires the following operations: join between the first and the fourth graph on the position of [BIRD]; restriction to the concept [STERNA]; join with the sixth graph on the position [STERNA], restriction to the concept [ARTIC_TERN], restriction of the generic concept [ARTIC_TERN] to an individual concept [ARTIC_TERN:"leslie"] and, finally, three repeated restrictions that relate the referent "white" to the generic concept [COLOUR], the referent "12p" to the generic concept [WEIGHT], and the referent "80cm" to the generic concept [SIZE].

2) There is almost the same derivation process leading from the second, third, and seventh canonical graph to the graph s:

```

g2: [BIRD] <---(part_of)--- [BODY_PART]

      (char)--- [SHAPE]

g3: [FEATHER:{*}]<---(loc)--- [BODY_PART]

      (char)--- [COLOUR]

g4: [BODY_PART] <---(is_a)--- [HEAD]

      (is_a)--- [BODY]

      (is_a)--- [WING: {*}@2]

      (is_a)--- [TAIL]

      (is_a)--- [LEG: {*} @2]

```

```

w: [BIRD] <---(part_of)--- [WING: {*}@2]
      (loc)---> [FEATHER]
      (char)--- [COLOUR: "white_and_blue"]
(part_of)--- [TAIL]
      (loc)---> [FEATHER]
      (char)--- [COLOUR: "white"]

```

The operations are the following ones: join between the second and the third canonical graph on the position of [BODY_PART]; join with the seventh canonical graph on the position [BODY_PART], repeated restriction of the concept [BODY_PART] to the two proper subtypes [WING:{*}@2] and [TAIL], and repeated restrictions that conform the generic concept [COLOUR] to its corresponding referents "white and blue" if it is localized on the wings, "white" if it is localized on the tail.

The thematic configuration represented by the graph w constitute a set of canonical and derived descriptions by the means of which we assert some physical aspects of a particular artic twin called Leslie. Even if haven't given a direct account of the description of the physical aspects of this bird, we are to derive it from a small basis of canonical graphs representing quite general thematic configurations that behave like autonomous, internally structured *modules* that interact and transform themselves following the four formation rules.

The interaction and transformation of quite simple, internally structured and general modules is one of the most prominent doctrines of the object-oriented approach of knowledge representation (*latu sensu*) in artificial intelligence (Cox 1987, Masini and alii 1989, Ferber 1990, Rumbaugh and alii 1991).

The practical idea that underlies this vision, is to construct a more or less small set of *general* (and *generic*, see below) configurational descriptions called "*libraries*" that are reutilisable in a great variety of applications. In deriving more and more specified "libraries" from the first,

general (and generic) ones, by the means of some basic "*methods*" (formation rules) and other, more specified methods, one could generate a *conceptual library-code* that describes in an appropriate way those informations of a knowledge source which are relevant in a given context of application. Knowledge description by the means of configurational entities and knowledge representation and formalization with conceptual graphs seems to us to be the appropriate way to realize this idea (see also Thaysse and alii 1989; Stockinger 1992).

As Sowa has pointed it out, the technique used to produce a derived graph representing a set of canonical and/or already derived (thematic) configurations as well as to prove that a given graph derives from a set of canonical graphs, is the *technique of recursive or again inductive definition*:

"First a small starting set of elements is given.

Then some operations are specified for generating new elements of the set from old elements.

Finally, the set is defined to be the set containing the starting elements, all others that can be derived from them by repeated application of the generating operations, and no other elements not so derivable.

The set resulting from these operations is said to be the closure of the starting set under the given generating operations" (Sowa 1984: 369).

The small starting set is given by the basis of canonical graphs; the generating operations are constituted by the principal formation rules, and the closure of the starting set is the set containing all derivable graphs, and no other graphs not so derivable.

The four canonical formation rules are in fact *rules of specification* of canonical graphs. They produce new graphs that represent (thematic) configurations which are more specified than the configurations from which they are derivable. As Sowa has shown it, the theory of partially ordered hierarchies applies also to entire sets of conceptual graphs and not only to concepts and conceptual relations (Sowa 1984:96 - 103).

Now, given the formal possibility to define a partially ordered hierarchy over sets of graphs, we need not only operations of specification of (thematic) configurations represented by conceptual graphs, but also operations of *generalization* that allow to elicit more general knowledge from more specific one.

The operation of generalization is called a *projection* of a graph v in a graph u . The Greek letter π is used to express a projection operator which has the following properties:

"For each concept c in v , πc is a concept in πv where $\text{type}(\pi c) \leq \text{type}(c)$. If c is individual, then $\text{referent}(c) = \text{referent}(\pi c)$. For each conceptual relation r in v , πr is a conceptual relation in πv where $\text{type}(\pi r) = \text{type}(r)$. If the i th arc of r is linked to a concept c in v , the i th arc of πr must be linked to πc in πv " (Sowa 1984:99).

Let us take the three canonical graphs from which we have derived the graph r .

g1: [BIRD] <---(char)--- [COLOUR]

(char)--- [WEIGHT: @*]

(char)--- [SIZE: @*]

g4: [BIRD] <---(is_a) --- [LARUS]

(is_a)--- [STERNA]

g6: [STERNA] <---(is_a)--- [SANDWICH_TERN]

(is_a)--- [ARTIC_TERN]

r: [ARTIC_TERN: "leslie"] <---(char)--- [COLOUR: "white"]

(char)--- [WEIGHT: "12p"]

(char)--- [SIZE: "80cm"]

Given the specialization/generalization hierarchy of graphs following the line [BIRD] < [STERNA] < [ARTIC_TERN], the graph r is the most specialized graph of all:

The projection of $g6$ in r is $g'6$: [ARTIC_TERN] restricted to an individual concept.

The projection of $g4$ in $g6$ is $g'4$: [STERNA] restricted to the proper subtype [ARTIC_TERN].

The projection of $g1$ in $g4$ is $g'1$: [BIRD] which is a copy of $g'4$.

The projection of g_1 in r is g_1 - the whole graph - where its generic concepts are restricted to individual concepts.

Every graph, that derives from another graph is a specialization of the last one and must therefore "contain" it as a subgraph that is necessarily more general than the entire graph. Projections of some more general graph in more specialized ones are neither necessarily one-to-one (it may happen that two different concepts or conceptual relations become equivalent in the goal domain of the projection or vice versa) nor necessarily unique (there may exist several different projections from one more general graph in a more specialized graph).

As Fargues & Catach (1985) and Fargues and alii (1986) have pointed it out, the operation of projection is closely related to the *unification or mapping formalism* that is used as a resolution mechanism in logical programming languages: "This (revised, P.S.) matching operation is defined as follows: We say that a graph v can be matched to a graph u if there exists a subgraph u' of u such that:

- + the conceptual relations are the same in v and u' ,
- + if the concepts c_i and c_j (respectively, d_i and d_j) are linked by the conceptual relation r in u (respectively in v), then, in the pairs (c_i, d_i) and (c_j, d_j) the first and the second concepts must be compatible (i.e. two concepts are compatible if there exists a maximal common restriction c_3 of c_1 and c_2 with the following conditions: $c_3 \leq c_1$, $c_3 \leq c_2$, and $c_3 \neq \perp$)" (Fargues and alii 1986:77).

As we have already seen, one of the major problems in knowledge description and representation is that it is maybe intrinsically impossible to conceive a description of an object that wouldn't keep any trace of the point of view from which it is elaborated, of the contexts for which it should be valid or, again, that could determine, once and for all, all possible changes, transformations or again evolutions of its object of reference.

The practical consequence is that a knowledge base must be conceived in such a way that it could be adapted (or that it could adapt itself) to new knowledges, to knowledges that change or again to knowledge that is relevant only in some contexts.

Since several years, a lot of formal researches have been done in the field of dynamic and partial models, especially in so-called non-standard logics (Gardenfors, McDermott, Moore) and in formal or cognitive semantics (Hintikka&Kulas, Kamp, Martin, Barwise&Perry). Almost all of these researches try to give a formal account of changing circumstances or contexts, of particular point of views or (mutual) epistemic states that influence the validity of a description of some object that evolve itself in time and in interaction with other objects.

Conceptual graph theory is totally compatible with these approaches. Following Hintikka and alii as well as Barwise&Perry, Sowa himself has sketched out a game-theoretical and situated ("circumstantial") approach of knowledge representation in the framework of conceptual graphs.

We cannot discuss here more systematically the interest of these new theories for knowledge description and representation and limit ourselves to a quite basic investigation of possible issues that concern the problem of changes in given (thematic) configurations that describe some object of reference.

There are three basic possibilities to modify a given knowledge base of conceptual graphs representing a set of (thematic) configurations:

- 1) the introduction of new conceptual graphs in the canonical basis;
- 2) the definition of new concept types and conceptual relations;
- 3) the attunement of the validity of a (thematic) configuration to a contexte by the means of nested graphs.

The *first possibility* is rather simple because it consists only in the enriching of a given set of canonical graphs by new graphs. The introduced new graphs, naturally, must be compatible with the existing ones.

The *second possibility*, the definition of new concept types and conceptual relations, is performed by the operation of abstraction (designated by the Greek letter λ) which maps an abstract canonical graph in a graph u .

Before discussing the operation of abstraction, let us take an exemple. In our set of thematic configurations describing physical aspects of various species of birds, we have taken into account only the fact that the several body parts of a bird are covered with feathers. Now, it is quite possible that somebody wants to obtain some more precise informations about a particular type of feathers like, for instance, the remex, the tectrix or again the down of a bird.

In order to satisfy such a request, there exists the possibility to define a new concept or again a new (thematic) dimension which - when unfolded - constitutes an entire graph representing new and appropriated knowledge about its object of reference. The introduction, for instance, of the new concept type [REMEX] will be as follows:

```
typeREMEX(x) is
  [FEATHER:*x]<---(loc)---[WING:{*}@2]

  (qty)--->[NUMBER]

  (char)--->[SIZE].
```

This definition stipulates that the remex is a feather which is located on both wings, that there is a certain quantity of such feathers and that they are also characterizable by their (morphological) size.

The definition procedure is written as follows:

type t(c) is u.

"Type" signifies that the definition introduces a new concept type, the expression "t" identifies the name of the new concept, "u" is the graph called the body to which the abstraction is mapped and "c" specifies the formal parameter that relies the new concept type with a generic concept in the body.

In our exemple, "t" refers to REMEX, "u" is the graph by the means of which REMEX is defined and "c" corresponds to the symbol "*x" specifying that in this definition [FEATHER] functions as a formal parameter. Simultaneously, it specifies, too, that REMEX will be handled as a subtype of FEATHER in a given partially ordered hierarchy of (thematic) dimensions or (thematic) configurations.

As Sowa has shown, the procedure of the definition of new concept types corresponds closely to the logical procedure of abstraction given by the lambda calculus (Sowa 1984: 105; Thaysse and alii 1989).

This procedure of definition can be extended to the definition of new conceptual relations. This is an interesting possibility given the fact that we can construct systematically from some hypothetically basic thematic functions more and more complex functions that apply only to quite particular kinds of (thematic) configurations.

For instance, one may assume a basic function called "link" that can apply as a kind of default relation to all types of dimensions in a given configuration, i.e.:

[DIMENSION]---(link)--->[DIMENSION].

In introducing more specified dimensions, the basic function "link" can be restricted to more appropriate functions that possess a syntactical behaviour that agrees with the structural organisation of these dimensions. This vision is near to that prevails in localistic case-theory (Gruber, Anderson, Petitot) assuming some basic spatio-temporal and actantial cases that can be enriched by more specific parameters growing out of the specific structural organization of a certain type of (thematic) configurations. Sowa, for instance, proposes the following definition of the casual function "agent":

relation AGNT(x,y) is [ACT:*x]<---(link)---[ENTITY]---(link)--->[ANIMATE:*y]

In using this new relation, we could represent the graph u:

[EAT]<---(link)---[ENTITY]---(link)--->[PERSON: "paul"]

by the graph v:

[EAT]---(agnt)--->[PERSON: "paul"].

There are several interests for using the procedure of the definition of new (thematic) functions represented by conceptual relations.

As we have already mentioned it, it systematizes the construction of more and more specified functions as, for instance, actantial functions or functions of spatio-temporal localization. In using that strategy, we are not committed to elaborate an uncontrollable open list of functions or relations as it is often the case in case-oriented semantic theories.

Functions or relations that are explicitly defined cannot apply to any configuration but only to those that display a structural organization that is compatible with them. In this sense, the systematic elaboration of more and more specified functions or relations derivable from some basic ones is very near to the philosophy and epistemology of gestalt-theory and structuralism.

The strategy to define, out from some basic functions or relations, more and more specified and specialized ones seems to be fruitful for combined projects that have to deal with natural language processing as well as with what is called expert knowledge as it is, for instance, accessible in written or spoken documents. Normally, in lexical semantics and linguistics, the set of used cases for the construction of lexical subcategorization frames is quite limited and general. But the same cases could not be used directly for the description of expert (or "world") knowledge because they are too general or underspecified. For instance the relation "agent" as defined in the upper graph cannot draw a difference between purely agentive and teleological roles that we need if want to reason about plan-structures; it cannot distinguish between a community of specialized actantial roles that work together in order to select, to establish and to execute a plan or again in order to revise a given plan, and so on. But at the same time, it can be considered as a basic function or relation which is common to all other, more specialized functions or relations related to action, interaction and planification.

The procedure of definition introduces two remarkable operations on conceptual graphs: the *condensation* of an entire graph to a concept type or a conceptual relation and, conversely, the *expansion* of a concept type or a conceptual relation into an entire graph.

Let us consider again our exemple of the definition of the concept [REMEX]: the concept [REMEX] is, given the context of our description, strictly equivalent with its defining graph. So, it could be seen on the one

hand as a simple (thematic) dimension and on the other hand as entire (thematic) configuration that takes place in a more specialized configuration describing, for instance, some physical aspects of the feathers of a bird.

As Greimas (1966) and others (Adam&Petitjean 1989) have already argued, the condensation of a definition-description to a single term or lexeme as well as the expansion of a single term or lexeme to a whole definitional or descriptive "text" is maybe one of the most fundamental operations in human discours-activity, no matter if this activity has a specialized technical or scientific character or if it takes place in our every day life.

In this sense the operations of condensation and expansion gives a formal account to the problem we have already pointed out, viz. that a configurational dimension could often be unfolded in an entire configuration that behaves like a more general but autonomously organized module in a given (thematic) configuration in which it is imbedded.

The procedure of definition of new concept types and conceptual relations behaves, quite obviously, like the Aristotelian type of definition that states necessary and sufficient conditions in terms of "genus et differentiae" for a given type or relation.

But it is clear, too, that this type of definition underestimates the role of the context in which such a definition could be valid. All definitions and descriptions have to stipulate conditions which must be satisfied if a given object could be taken into consideration by them. In this sense, the so-called Aristotelian type of definition is necessarily valid even for so-called prototypical definitions. It stipulates only what can be hold to be true and how we can do this. Without this basic principle, no communication would be possible.

Neverthelesse, in accordance with Putnam (1976), Eikmeyer (1981) or again Lewis (1969), that principle could be applied only given a certain context, a certain point of view, a certain period or again a certain place. As Barwise puts it, "an informational situation s (is factored) into two parts, the representation S and its embedding circumstances c " (Barwise 1989: 142).

This leads us to the *third possibility* of the enriching of a KB that is by the means of context-dependent descriptions.

Definitions are attuned here to a *set of context-dependent schemata* expressing specific point of views concerning an object of reference. The several points of views can but must not necessarily be incompatible.

For instance our statuette in the Louvre can be "seen" and interpreted by a simple tourist, by an historian of arts, by a sculpturer, by a specialist of Christian motifs, by a specialist of the conservation of ancient objects, and so on.

We have also to distinguish between partial incompatibility and total incompatibility: in the first case a subpart of two conflicting descriptions is common to both, in the second part there isn't any common subpart at all and the two descriptions are not conflicting but incommensurable.

The problem that arises here, is, how to distinguish between two different point of views or again two different contexts. One - rather empirical - possibility is to proceed to tests of satisfaction: the description of the statuette taking into account the point of view of the historian of arts, is it sufficiently relevant for the point of view of a specialist of Christian motives, for the point of view of a specialist of the conservation of ancient objects, for the point of view of a sculpturer, ... ?

In distinguishing the several point of views, another problem to be solved is what could be considered as the common subpart that is shared by at least a subset of these point of views. This is important for the construction of very generic (thematic) configurations that are underspecified with respect to a given set of point of views or contexts.

Those very generic (thematic) configurations function as a kind of *common canonical basis* that enables and controls the communication between the several more or less distinct point of views and contexts *which have all their own canonical basis "containing"* the relevant but not globally true (thematic) configurations.

With these last considerations we meet the same problems as in distributed artificial intelligence working on the modelization and formalization of the forms of interaction and communication in a "community" of agents ("actors") that cooperate in order to resolve a problem.

The several canonical basis provided with the four canonical formation rules as well as with the operation of projection constitute, in a certain sense, a KB that represents the knowledge one actor has of the object of reference whereas the common canonical basis with the four rules and the operation of projection constitutes "communication protocols" between the actors of a community.

From a formal point of view the procedure of schematic definition is equivalent to the procedure of Aristotelian definition operating by "genus et differentiae" Each schematic type definition is a monadic abstraction λc u which is written as follows:

schema for $t(c)$ is u

Given that there are several point of views with respect to an object of reference, there exists a set of schemata which Sowa calls - following Putnam (1962) - *schematic clusters*:

"A schematic cluster for a type t is a set of monadic abstractions $\{\lambda a_1 u_1, \dots, \lambda a_n u_n\}$ where each formal parameter a_i is of type t . Each abstraction $\lambda a_i u_i$ in the set is called a *schema* for the type t " (Sowa 1984:129).

Here is a very simple exemple of a schematic cluster that represents several views on an artic tern: there are a point of view that concerns its physical aspects, a point of view that concerns its alimentation, and a point of view that concerns its reproduction.

1) schema for ARTIC_TERN (x) is
 [STERNA] <---(char)--- [COLOUR: "white"]

(char)--- [WEIGHT: "12p"]

(char)--- [SIZE: "80cm"]

(poss)--- [WING: {*}@2]<---(char)---[SHAPE]

(loc)---> [FEATHER]

(char)--- [COLOUR: "white_and_blue"]

(poss)--- [TAIL]<---(char)---[SHAPE]

(loc)---> [FEATHER]

(char)--- [COLOUR: "white"]

2) schema for ARTIC_TERN (x) is
 [BIRD]<---(agt)---[ALIMENTATION]

(obj)---->[EDIBLE_OBJECT: {crustaceous, seaweed, *}]

3) schema for ARTIC_TERN (x) is
 [STERNA]<---(agt)---[REPRODUCTION]

(obj)---[EGG: {2 | 3}]

(loc_tmp)---[MONTH: {april, may}]

(tmps_int)---[LENGTH: "33-35 days"]

Even if the quality of these descriptions is quite discutable, they show, nevertheless, the interest of the construction of such schematic clusters.

Each schematic definition relies either on a canonical graph or some graph that is derivable from a given canonical basis. The first schematic definition, for instance, relies on a derived graph that specifies

a (thematic) configuration which is appropriate to the description of the physical aspects of a sub-species of birds. Hypothetically we can assume that the second and the third schematic definitions refer to (thematic) configurations that are derivable from canonical basis that constitute some fundamental knowledge-assumptions concerning respectively animal alimentation and reproduction. In this sense the three schematic definitions are asserted by three (groups of) actor(s) that behave like specialists who intervene together or separately in order to highlight one or more types of characteristics of an arctic tern. But given the three canonical basis defining the "knowledge structure" of our "community" of experts, they could as well intervene in a lot of other circumstances related either to the identification of physical properties of a bird or to its reproduction cycles or again to its nutritional habitudes. As a "communication protocol" between the community of experts could serve a generic description that is shared by the whole community as, for instance, that birds are - normally but not necessarily - flying animals (another possibility to elaborate such a communication protocol is to assert a kind of intuitive or experiential description like in cognitive semantics).

The strategy to produce schematic definitions is indeed a very interesting one for the elicitation and description of several knowledge standards as we have defined it in the introduction of this article. A knowledge standard is, *eo ipso*, bounded to a type of points of view which is assumed by an actor. This is not only true for thematic knowledge but also for linguistic (lexical and grammatical) knowledge, visual knowledge or again knowledge concerning the (formal and physical) organization of a document - a fact which is attested, for instance, by the existence of several (international) standards in the production of technical documents. As far as the description of lexical knowledge is concerned, it is intuitively clear that the meaning of a lexeme depends highly on the contexts in which it is used as well as on a pre-supposed semantic theory to which it refers. The lexeme "heart" - "coeur" in French - refers, among other things, to the physiological organ, to an edible object, to a sentimental object, to an epistemic object, and so on (cf. Mel'cuk). By the means of a schematic type definition, the several meanings of the lexeme "coeur" will be broken up following several prominent point of views (*viz.* the point of view of physiology, the point of view of alimentation, the point of view problem solving, ...) and for each one there will be coined an appropriate lexical description. As a "communication protocol" between these several meanings, there can be stipulated either a rather generic description as structural semanticists prefer it to do in soliciting the notion of an "archi-

sememe" (cf. Pottier 1974, Greimas 1966) - i.e. "coeur" is a "central organ" - or an intuitive or "experiential" description as it prevails in actual cognitive semantics (Lakoff:1987).

We have have mentioned already several times the notion of context in stipulating that it must obligatorily taken into account by the description and modelization of knowledge. It is, indeed, highly artificial to speak about (thematic) configurations without taking into account the "environnement" in which they take place and with which they interact. Furthermore, it doesn't make much sense to introduce schematic definitions without making further investigations into the context for which a schematic definition is provided.

There are three particular problems concerning the description of contexts. The first one consists in the difficulty to identify a context or a type of contexts and to distinguish them from other contexts or type of contexts. It is more or less unresolved and we have to proceed with quite empirical experiments of trial and error. One experiment is the test of satisfaction that we have already quoted: given a certain type of request(s) concerning an object of reference, can a description provide satisfying (relevant as well as verifiable or falsifiable) responses. If yes, it is appropriate to the context which is implicitly vehiculated by the requests; if not, it is not necessarily false but possesses another orientation, another level of relevancy that reposition it in another context (or in another type of contexts).

The second problem concerns a canonical description of the context, viz. some kind of hypothesis by the means of which we approach and analyse this notion. Following several investigations in formal pragmatics we accept a little set of basic dimensions that figure as coordinates following which one a context could be characterized. Among these dimensions we count the following ones: [ACTOR], [POINT_OF_VIEW], [TIME], [SPACE], and [ASSERT] (Ploteny&Stockinger 1993). It would be too long to justify them here. Let us note only that they are motivated by the philosophical and epistemological principle of contractualism or conventionalism as proposed by Rawls (19) or Lewis (1969). The important point here is that the quoted dimensions could be unfolded into entire graphs or set of graphs. In this sense we are able to account of contexts in a rather general and non-specified way as well as in ways that are more and more specialized. Furthermore, there could exist "contexts in a context", viz. there could exist nested contexts

where a given context on the level n could be "viewed" under several contexts on the level $n-1$.

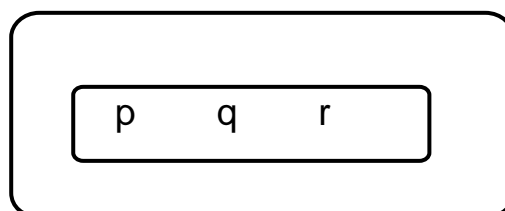
In speaking of the context in terms of conceptual graphs, we have already revealed the fact that a context is describable as a (thematic) configuration that dominates another configuration (or a set of another configurations). Therefore, the referent of the configuration describing a context, is again a dimension, relation or a whole configuration and neither an object "in the world" nor a linguistic or visual entity.

The representation and formalization of contextualized configurations (viz. of configurations that have as its referent another (set of) configuration(s)) are handled by nested graphs:

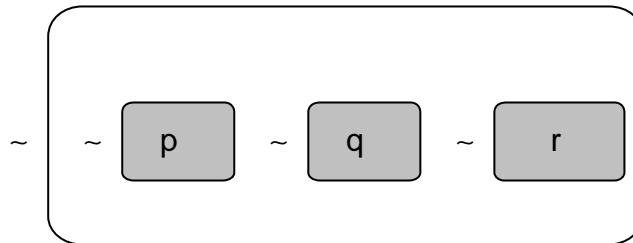
"Definition: Let p be a concept of type PROPOSITION whose referent is the set $\{u_1, \dots, u_n\}$ of conceptual graphs: [PROPOSITION: $\{u_1, \dots, u_n\}$]. Then each graph u_i in referent(p) is said to be asserted by the proposition p , and u_i is said to occur in the context of p " (Sowa 1984:139).

Our label [ASSERT] corresponds to the label [PROPOSITION] used by Sowa who adopts, here, a terminology which is closely related to that in linguistics where a distinction is made between the propositional content of a phrase and its modal frame ("modal" is used in a very wide sense which is more or less equivalent with the notion of "enunciation" in pragma-linguistics or again with the notion of "propositional attitude" in ordinary language philosophy).

The representation of contextualized configurations by the means of nested graphs is derived, following Sowa, from the existential graphs developed by Peirce. The several Boolean operators defined in the propositional calculus can be reduced to negation and conjunction. In order to represent them by visual means, Peirce represented them by the means of nested negative contexts where one context is visualized by a box: In this way, the conjunction $(p \wedge q \wedge r)$ can be represented as follows:



The disjunction $(p \vee q \vee r)$ corresponds to $\neg(\neg p \wedge \neg q \wedge \neg r)$ and can be represented as follows by nested negative contexts:



Every box corresponds to a conceptual graph, the nested boxes correspond to conceptual graphs that are in the field of the referent of the concept [ASSERT] of the dominating graph, viz. of the graph representing the nesting box(es), and the symbol of negation corresponds to a monadic conceptual relation - or operation - that applies to a whole graph:

$$\neg[\text{ASSERT: } \{\neg[p] \neg[q] \neg[r]\}]$$

In generalizing the technique of nested (negative) contexts and in assuming that there are n levels of contextual nesting, we are able now to take into account the partial specificity of contextualized (thematic) configuration that can partially overlap with other context-dependent configurations - as Hendrix has pointed it out - as well as the dynamic construction of knowledge, the problems of multiple reference, the scope of quantifiers or again the scope of negation.

Let us discuss here only the problem of the scope of negation. The relation or operation of negation, as it has been introduced above, applies or has in its scope the whole configuration represented by a conceptual graph. For instance, the assertion that an ostrich doesn't fly would be represented as follows:

$$[\text{ASSERT: } \neg [[\text{OSTRICH}] < \text{---(agt)---} [\text{FLY}]]].$$

Nevertheless, there are situations, in which one might give more precise informations in the sense that it is not the ostrich that flies or that is not flying that is a (habitual) activity of the ostrich or even that it is not (intentional) agency that characterizes the relation between an ostrich and flying. Therefore we would like to handle such graphs as the following ones:

- a) [ASSERT: [¬OSTRICH]<---(agt)---[FLY]]
- b) [ASSERT: [OSTRICH]<---(agt)---[¬FLY]]
- c) [ASSERT: [OSTRICH]<---(¬agt)---[FLY]].

In order to handle such graphs, we have to define for the first two graphs a notion for the *negated dimension* represented by a *negated concept inside a graph*.

We know already how to define a negated dimension, namely by the procedure of type definition, but we do not yet know what should be the body of that definition.

Therefore, let us consider more in detail the first graph (graph a) asserting that it is not the ostrich that flies.

This assertion supplies in fact two different assertions: the first one asserts that birds fly (or, again, that there are animals that fly):

- i) [ASSERT: [BIRD]<---(agt)---[FLY]]
- and the second one that refutes that this is the case for ostriches:
- ii) ¬[ASSERT: [OSTRICH]]

The first assertion constitutes the outermost context (level 0) that is limited to an epistemical state E1 of an actor in which it is true that birds fly; the second assertion constitutes a nested context on level 1 that is limited to an epistemical state E2 of an actor in which the epistemical state of the outermost context is negated for ostriches. The context on level 0 dominates the context on level 1 or, in other words, the epistemic state E2 in the context on level 1 presupposes the epistemic state E1 in the context in level 0.

In distinguishing between the two different epistemic states E1 and E2 localized on two different contexts where E1 dominates E2, we can give an explicit account of the implicit or condensed information represented by graph a. Therefore, the expanded version of the first graph looks like this:

[ASSERT: {[BIRD]<---(agt)---[FLY], ¬ASSERT:[OSTRICH]}].

The expanded version of graph a corresponds exactly to the description of its meaning in terms of nested contexts and the relation of domination. So, in considering the expanded version, we know now, too, what is the "body" that we need for the definition of a negated dimension represented by a negated concept:

type $\neg t(x)$ is $[T:*x], \neg[[t:*x]]$ (Sowa 1984:147)

or, again:

type $\neg t(x)$ is $[\text{ASSERT: } \{[T:*x], \neg[\text{ASSERT: } [t:*x]]\}]$.

The second graph asserting that it is not the activity of flying that characterizes ostriches, works like the first graph. The outermost context is restricted to an epistemic state $E1$ of an actor in which it is true that the activity of flying characterizes birds; the context on level 1 is limited to an epistemic state $E2$ of an actor that refutes the assumption in $E1$, where $E1$ dominates $E2$.

The third graph, finally, needs the following definition of the negation of a configurational function represented by a conceptual relation:

relation $\neg r(x_1, x_2, \dots, x_n)$ is
 $[t_1:*x_1] [t_2:*x] \dots [t_n:*x_n]$
 $\neg[(r)-$
 $<---[t_1:*x_1]$
 $<---[t_2:*x_2]$
 $<---[t_n:*x_n]]$ (Sowa:1984:148).

Note, that the exemple of the inability of the ostrich to fly is often quoted in the specialized litterature as an exemple that causes serious problems to the inheritance mecanism used in partially ordered hierarchies of conceptual graphs, structured objects, frames and so on. A special type of non-standard logics - default logic (Reiter) - has been developed that should tackle with that kind of problems.

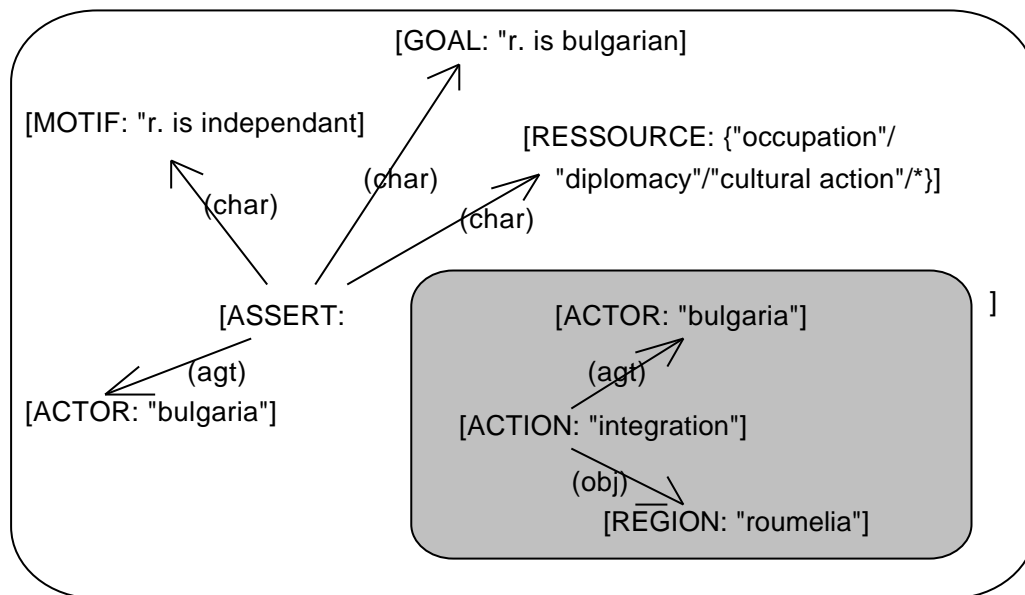
To give an account of the problem of negation in terms of nested graphs are not incompatible with default logic given the fact that conceptual graphs can be "translated" in the language of FOPC that can be attuned by special operators to the requirements of default logic. But the objectives that we want to pursue here is to take explicitly into account pragmatic or epistemic factors that intervene in the revision of a given "theory" of some object of reference, or again, in other words, to

elaborate a more pragmatic oriented conceptual and formal framework of the "negociation" of the validity of a knowledge standards between actors that have to find a solution (a new "equilibrium") for an epistemic conflict that opposes them.

Even if the example of the scope of a negation is a rather specialized one, the consequences of the use of the representation formalism of nested graphs in knowledge description and representation are not only general but also important.

Let us take the already quoted exemple of the description of actions and plan-structures in conflicting situations opposing two or n actors. A scenario representing such situations of conflicts (also called "crisis") must be composed by at least three major types of configurations: a first type of configurations that describes the manifested actions that are relevant for the evolution of a given crisis, a second type of configurations that describes the plannification of the manifested actions as well as the goals that are pursued by an actor, and a third type of configurations that describes the "point of view" (the "epistemical state") of an actor with respect to the crisis and to the context of the crisis constituted, for instance, by the actors that are in opposition to goals pursued by the actor.

In considering only the first and the second type of configurations, we have a nested representation that looks like as follows:



This representation refers to a (very simplified) description of the first war between Bulgaria and Serbia (1885) that asserts that Bulgaria pursues a basic action which is the obtaining of Eastern Roumelia - a region around Plovdiv in actual Bulgaria - and that is determined by a plan that the actor Bulgaria has at its disposal. The plan itself exhibits the motifs, goals and ressources of possible actions that constitute several options for the realization of the goal(s).

The important aspect here is that the two thematic configurations representing respectively the plan structure and the manifested basic action are represented by nested graphs where the outer graph (that "visualizes" the plan structure) dominates the inner graph (that "visualizes" the manifested basic action).

Given this framework, it becomes possible to "simulate" not only the manifested changes that structure the evolution of a crisis but also the motivating features that intervene and orient such changes. We have, here, especially, the possibility to "simulate" the selection and the decision of a particular basic action given a "pool" of possible actions that constitute the "ressources" of an actor to realize a goal. Another possibility is, in comparing different plan-structures, to infer with a certain probability the selection of a particular basic action given a certain type of motifs as well as a certain type of goals. Naturally, there is again the third type of

configurations taking into account the particular "point of view" or "epistemic state" of an actor with respect to a crisis and its context that restricts the choice of a possible action in order to satisfy a given goal. We will not introduce here this component of a scenario describing a conflictual situation and its evolution but indicate only that it contextualizes again not only the manifested actions and the corresponding context but also the plan structures which constitute its referents. Indeed, the introduction of this third component leads us to a description of conflictual situations that are closely related to those produced in the theoretical context of game theory (Schelling).

As we have already stated it, knowledge description and representation could be done on several levels of generality or specificity. The above represented description is localized on a very general level that asserts only facts that are related to the basic action and the basic plan that characterizes a conflictual situation. Like Schank&Abelson, one could decompose, for instance, the basic action in a series of more particular actions which together realize the basic action. For instance, the first serbo-bulgarian war could be decomposed in the following series of actions: territorial claim of Bulgaria - occupation of Roumelia by Bulgaria - armed conflict between Bulgaria and Serbia - defeat of Serbia - threat of occupation of Serbia by Bulgaria - intervention of Austria in order to stop the war - acknowledgment of the unification of Roumelia and Bulgaria by Austria, Germany and Russia.

Each particular action or action sequence as well as the succession from one particular action sequence to another is motivated by a plan-structure that conforms on the one hand to the basic plan described above and on the other hand to the given action sequence. So, the description of the evolution of a conflictual situation takes the representation of temporally referenced nested graphs that, in the most simple cases, "simulates" the progressive realization of a principal or basic goal by the means of a motivated choice between a "pool" of possible resources that are more or less appropriate with respect to the epistemic states of the actor. In this sense the framework of nested graphs representing contextualized configurations constitutes an explanative tentative of what Schank&Abelson (1976) call "named" or "stereotyped" plans as well as of plan revisions.

In order to conclude our discussion concerning the framework of nested graph theory we want to emphasize again that it is an appropriate

tool for the representation and formalization of descriptions that have to take into account what is actually called the "multi-expertise", that is, the existence of different and divergent knowledge standards in a given domain of reference.