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CONCEPTUAL ANALYSIS, KNOWLEDGE MANAGEMENT, AND CONCEPTUAL GRAPH THEORY[1]

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Our principal objective in this article is to develop a conceptual framework that should permit us to handle some major descriptive problems in the conception of knowledge based systems. In order to be able to put forward in a systematic way our conception of knowledge representation (KR), we will discuss in the first section some central problems of knowledge description such as the notion of "knowledge standard" or the problem of recursive definition of a set of configurations (of intensional entities) that describe or define some given domain of reference. We put forward, furthermore, some hypotheses concerning the domain of reference of KR that we call "knowledge management". In the second section, we will introduce the conceptual graph theory developed mainly by Sowa (1984) and try to give a more formal account of KR.

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 quite vague.

It is not our intention to give a historical survey of that notion nor to proceed to a critical enumeration of the several topics that are covered by it. Our objective 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 discuss in the first section some central problems of knowledge description. In the second section, we will introduce the conceptual graph theory developed mainly by Sowa (1984) and try to give a more formal account of KR.

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First Part:
The Conceptual Level of Knowledge Description

1) *Knowledge Description*

There are a lot of hypotheses 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 have not any serious proof to enable us to choose between these theories and others. The sole possibility that we have is to put forward competing *descriptions* and to *test their validity relative to a context* in which knowledge becomes "active" and observable.

Let us assume that we are in the Louvre museum, in Paris, and that our attention is caught by a wooden, monochrome statuette of the 14th century, in gothic style, representing the Virgin Mary holding the crucified Christ in her arms. Basically, our attention could be satisfied in two ways: either we have "enough information" 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 do not have "enough information" and, in this case, we are obliged to consult an information source that is better informed.

Let us assume, now, that the satisfaction of our attention corresponds to the characterization of the statuette that we have given above ("statuette", "wooden", "monochrome", ...). If we are able to satisfy our attention alone, we must, necessarily, possess ("in our heads") a kind of model or schema with the following generic features:

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

It is only the assumption that such a model exists that allows us to identify the above mentioned statuette:

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

If we do not have this model "in our heads", we have to look for it elsewhere –in other words, we have to consult a source of information, not any source of information but a relevant source of information 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 constitutes a kind of *vision* or 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 about an object and the *expressive form* that we are free to choose in order to represent this model or schema. Indeed, the above model with its different labels constitutes, properly speaking, the *representation* of a (mental, social, ...) model that gives us a view of an object. We could have chosen for the labels SCULPTURE, PERIOD, and so on, some arbitrary symbols (for example, the letters S or P) or again some more perceptively oriented symbols (for example, a schematic figure instead of the label SCULPTURE or a diamond instead of the label PERIOD). Such changes do not affect at all that which is generally called the descriptive power and adequacy of the model. It only affects *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 arbitrary.

Our "model" representing a certain vision of the statuette, which is exposed in the Louvre museum, is, in its actual form, only a very incomplete outline of all those of someone's activities that we could possibly observe in a given situation. It says nothing, for instance, of the relationships that hold between the several quoted generic features. The identification of these relationships is, 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 asserts the existence of a set of generic features, he could simultaneously assert different *configurations* of them. In our example, someone asserts two configurations with the triplet DATATION, MOTIF and STATUETTE: with the first one, he asserts the temporal location of the statuette (14th century), but with the second one, he asserts the temporal location of the motif (he ascertains, for instance, the fact that the motif represented by the statuette has existed since the first century of the Christian era).

The central notion here is the notion of *configuration,* which expresses the hypothesis that knowledge is a "structured whole" or, in a more technical terminology, an intensional entity that could be represented informally, for our example, 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: "The Virgin Mary holding in her arms the crucified Christ".

The internal structure of this configuration is a very simple one: 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 of one another (i.e., between which no relationship exists).

The label "is characterized by" does not represent a defined relation. It could be substituted by an arrow or an arbitrary symbol but the substitution of representational figures would not change anything in the meaning of the relation. Intuitively, we prefer to label the relation between SCULPTURE and PERIOD with the name "is localized by", suggesting by this change that there is a relation of temporal location between these two features. Nevertheless, if we do not have a *theory* of temporal location or of the relation of characterization, the use of different labels is completely arbitrary and has not 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 the canonical types of relations we need for the description of knowledge.

The above outlined model only labels the dimensions DATATION, MOTIVE, CHROMATICS, and so on. But suppose, now, that we "ask" our model: what is MOTIVE?, what is DATATION?, what is CHROMATICS? If our model should explain what these dimensions mean, it must incorporate theories of them –in the most simple case, definitions and descriptions.

In this sense, a structural configuration like our model is itself composed of other configurations which are either more general than the configuration that "houses" them or which constitutes a model to which the configuration (or parts of it) refers (refer).

Let us assume, furthermore, that we are not entirely satisfied by a response given following the quoted model. We could be dissatisfied, for instance, because the response is too general or because it leaves out several aspects such as the identity of the artist who is the creator of the sculpture, the place of its production, its history or its cultural context.

Those possible reactions to a given response lead us to take into account that knowledge and therefore also its description is *context-dependent*. There does not 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 *configurational contextualization*. As we will see again later on, a configurational contextualization may be decomposed in an "outer" configuration (the so-called contextual configuration) that dominates one or more "inner" configurations (the so-called contextualized configuration).

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 ask ourselves 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 in question, one source might give a general description in the spirit of the above outlined model; another source might give a more specific one focusing on, let us say, the motif of the statuette, its history, its symbolic aura or its relationships with other Christian symbols; a third source might introduce complementary information "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 information –it might ascertain, for instance, that the authorship of the statuette is not individual but collective or that the statuette is not a statuette of the 14th century but of the beginning of the 15th century, and so on.

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

Our example of the different sources of information is, as we feel, a quite realistic one that refers to what is sometimes called a context of multi-expertise, i.e., a context that is characterized by a multiplicity or a *community of experts* who deal with an object or a situation. A configuration referring to such a situation is normally a very complex one that we do not wish to describe as such and by itself. We would much prefer to identify and describe more basic configurations and a set of rules with which we are able –as in generative grammar– to derive or to generate such a complex configuration.

The elaboration of such "configurational grammar" encounters several major problems for which we have to find some solutions:

a) of all the information that constitutes a complex configuration, which information should be described?;

b) what are the basic assumptions that underlie the information that we have to describe?;

c) what are the "mechanisms" that permit that information from the basic assumptions be derived?;

d) among the information that should be described, which could be considered as given or known information and which should be considered as novel or unknown?;

e) what is the "nature" of the controversy concerning the information that should be described?;

f) how should we lead someone through all this information in order to enable him to satisfy his objectives?

Problem (a) refers to the 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, the *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 part 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 which of the differences in the representative set of knowledge is (are) within 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 (f), finally, to the question 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 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 second section of this article, we will try to give a more systematic account of these notions which constitute, from 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, with a language of representation (*stricto sensu*) by the means of which a descriptive model may be expressed and communicated.

2) *Knowledge Management*

Until 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 here is what kind of knowledge this model exactly represents. 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 communicated 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 correspondence 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– on the convention T (Davidson 1990) that holds between a given metalanguage of 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 (Stockinger 1993):

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

It is out of question to furnish here a more detailed account of the hypothetical structure of knowledge management (Vogel 1988, Hart 1988). Our intention is only to present some general aspects of the component "document".

In speaking of the component "document" that constitutes one major part of knowledge management, we do not necessarily restrict 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 media by the means of which information or knowledge is communicated and conserved. In this sense, a document can be a spoken one, a visual one, a gestural one, and it can be physically realized by several supports including 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 information 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 communicate, to store, and to maintain information or knowledge.

The next question that arises is how we could approach the notion of "document" as a structured whole of information and knowledge. We put forward the hypothesis that the document is organized into 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 medium 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 distinctions to draw. The first one concerns the fact that the topic or 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 example of the statuette, there may exist, on the one hand, one or more knowledge standards concerning this object and, on the other hand, one or more codes of expression of these knowledge standards –a linguistic code or a visual code or 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 Hymes, 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 statuette.

In this sense, we have to deal with several types and sets of knowledge standards (or "conventions" in the sense of Lewis 1969): one type concerns the set of available thematic knowledge standards, another type concerns the set of available linguistic knowledge standards or visual knowledge standards. More generally, *every level of the document articulates a certain type of knowledge standards.*

The production or 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 for the construction of KBS it requires not only the coordination of different competences but also a rather special architecture of a KBS, which is the one used in distributed artificial intelligence and in multi-agent systems where a "community" of specialized actors cooperates for the solution of a given problem (Bond and Gasser (eds.) 1988, Gleizes and Glize 1990).

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

The second 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 –as van Dijk (1977) puts it– the semantic macrostructures "behind" them. The major problem here is the identification and stabilization of a thematic standard or a semantic macrostructure. Indeed, the reconstruction of a thematic standard already presupposes 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, whether this knowledge is completely or only partially expressed, and stored in one, two or *n* physically existing documents.

This approach undoubtedly prevails in existing KBS such as, for instance, in expert systems or in computer assisted tutorial systems. But nothing prevents us from drawing a more general definition of knowledge based systems, also including 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 retain is that the two quoted perspectives presuppose each other in the sense that in more developed KBS for knowledge management the translation of thematic knowledge into a language of expression and the access from linguistic or textual sources to thematic knowledge are just as important as the manipulation of purely thematic or expert-knowledge (see, for instance, Lytje 1990).

In order to deal with a document, we have to elaborate *descriptions* that refer to the different 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 hypotheses concerning possible canonical structures of the several levels that constitute a document, on the one hand, and concerning the structure of the descriptive metalanguage itself, on the other hand.

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

As far as the different levels of a document are concerned, there are, in particular, the level of the formal and physical organization of documents as well as the level of the languages of expression, especially, the natural language system, which 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 exist quite important problems that are often due to a too specific or to a too particular language-dependent definition of descriptive metaterms, there exists nevertheless a more general consensus among linguists on how to tackle morphological, syntactical and lexico-syntactical questions. Most of the problems are either problems concerning the choice of an appropiate formal theory for linguistic descriptions or problems concerning the limits of the object of reference of linguistics.

The latter greatly influences the approach of natural language semantics. There is one extreme version –defended, for instance, by Jackendoff (1983, 1990)– 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 no semantics exists at all or, in other words, that natural language determines meaning in general.

We will not enter into this debate. Nevertheless, we think that there are good methodological reasons to drastically limit the object of linguistics and to reserve most of the semantic and pragmatic questions to what we call here the thematic level of a document. In this sense, the description of a linguistic standard or a standard of any other semiotic system by which a thematic standard becomes accessible and is communicated has to take into account principally:

a) the *expressive unities* (the "words") that constitute a language of expression;

b) the *referential value* of each expressive unity in respect of a given thematic standard as well as the *axiological or intensional distribution* of the positions that an expressive unity occupies in the language of expression;

c) the *rules* that permit *higher ordered expressive unities* ("syntagma", phrases, ...) to be produced.

Note that this claim is not as reductionist as it may seem. We must not confuse, for instance, the expressive unities called "words" with a lexicological or terminological acceptation in the sense of so-called (semantically) "full words".

There are not only highly specified thematic standards referring, for instance, to technical or cultural objects of reference (like our description of the statuette in the Louvre) but also a good variety of generic themes corresponding more or less to common sense knowledge standards like space, time, action, reality, and so on. Such themes are commonly encoded by the so-called syncategorematic expressive unities that will not change, or will change only very slightly, from one given standard of a language of expression to another standard. The reason is simply a kind of general agreement or tacit convention that for highly recurrent themes, it is more economical to use a fairly fixed set of expressive unities than to let them be expressed differently by different speakers.

Concerning the so-called lexical polysemy, let us mention only that it is highly constrained by the axiological or intensional distribution and by its insertion in higher ordered expressive unities as well as by the fact that it is quite often due to a kind of underspecification with respect to a given and relatively specialized thematic standard. The phenomenon of the lexical underspecification is, in a certain sense, the inverse phenomenon of the repetitive character of the use of a fixed set of expressive unities in order to account for generic themes. At least, as far as common language standards are concerned, it is out of the question to create for each new thematic standard, new expressive unities which would lead to a kind of quantitative explosion of the number of expressive unities –as is the case in the so-called *Fachsprachen* ("specialized languages") and which could strongly prohibit the communicative task of a common language.

In any case, the point that we want to stress here is that the description of a standard of a given (verbal or non-verbal) language of expression proceeds with respect to the three points quoted above: the first point deals with the extensional values of an expressive unity, the second, with the intensional values of an expressive unity and the third, with the constructional –or syntactical– patterns and rules of a language of expression.

Let us consider the third point of our methodological stipulation. The representative set of configurations corresponds to all "phrases" (or "phrase structures") that, given a set of canonical configurations (of assumed "primitive" phrase structures) and several formation rules, could be recursively generated by a grammar. This is the program initiated by Chomsky and actually largely assumed to be a correct one. Given a derived phrase structure, there exist, necessarily, not only some more specific configurations but also more general ones. Therefore, it is correct to assume that the recursive definition of a set of phrase structures relies also on the operation of configurational projection. Concerning the configurational definition, it is always possible to introduce, in a given grammar, new patterns and rules that must be compatible with the basic assumptions, with the canonical basis of the grammar. Furthermore, configurational condensation and expansion are quite usual in structural and generative descriptions where a symbolic term like "P" for "phrase" or "NP" for "nominal phrase" can be substituted by (expanded) appropriate structural configurations. The operations of configurational contextualization, finally, permit to take into account not only modal frames that modify a phrase structure but also different sets of "primitive" phrase structures that correspond to different (linguistic, ...) competences.

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, a 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 this information is 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 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 sufficient for the access of relevant information in a textual database (see, for example, the lexical information retrieval system GRATEX, developed by Lytje (1993) as well as for the "navigation" in such a database. Let us note again, that this is true, too, for the construction of non-linguistic interfaces like graphic interfaces or, more generally, for multimedia (multimodal) interfaces (May 1993).

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 develop, instead of producing a huge amount of physically existing documents, a big KB containing a set of classes of generic libraries 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 libraries will be activated and, by the means of a text-production system, the user will obtain a "personalized" document that communicates the wanted information to him. Here, again, it is out of the question to undertake the constitution of such libraries by the means of linguistic theories or methods. In order to develop a general architecture of such libraries and the thematic configurations that are represented by them, we have to appeal to what is called rich and domain specific knowledge or "expert-knowledge". The real problem that arises here is how we can capture the thematic level, how we can, hypothetically, deal with it.

We have already quoted the existence of a set of thematic standards describing (generic) situations of "time", "space", "action", "real situation", "possible situation", "counterfactual situation", and so on. This set of thematic standards is, at least hypothetically, understandable by the means of the description of corresponding linguistic expressions as well as by the means of appropriate formal theories (logic of time, action, ...).

Another set of thematic standards which is very important for the constitution of electronical libraries can be approached, again hypothetically, by a completely different theoretical tradition, which is that of classical rhetoric. It is K. McKeown who has been one of the first to realize the high interest of classical rhetoric for a thematic approach of text generation (McKeown 1985). Since her seminal work, several researches have been done in this direction reusing and actualizing the theoretical and practical insights of classical rhetoric in order to develop text understanding and text generation systems, methodologies of knowledge acquisition as well as thematic library-codes.

We cannot deal here extensively with the rhetorical approach. Let us quote only very general lines of it. In rhetoric, there exists a well-known distinction between the "inventio", the "dispositio", the "elocutio", the "actio", and the "memoria" (Lausberg 1963).

The *inventio* deals with the elicitation of themes that are relevant for a given purpose, the *dispositio,* with the structuring of the elicited themes in ordered sequences, the *elocutio,* with the choice of the most appropriate "verbal sublanguage" in order to express and to communicate a thematic standard, the *actio,* with the real communication that is sometimes also called the *pronunciatio* of a thematic standard, and the *memoria* –as its name already indicates–, with the memorisation of a thematic standard and adapted reuse in other situations.

The parallels between these distinctions in classical rhetoric and our own conception of the object "document" are fairly obvious: the "inventio" and the "dispositio" correspond to the thematic level of a document; the "elocutio", to the level of the languages of expression; the "actio" or "pronunciatio", to the level of the support; and the "memoria", to the reuse of thematic library-codes.

Let us consider succintly the "inventio" and the "dispositio". Given a certain context of communication as well as the life-cycle of a document, the "inventio" proposes two procedures for the elicitation of relevant themes:

– a *heuristic procedure by the means of the systematic questioning of an object of reference:* how?, where?, who?, when?, ... (note that the systematicity of this procedure depends on the existence of thematic standards of the set of those standards that deal with general and generic situations as "time", "space", "reality", "modality", "action", and so on);

– a *heuristic procedure by the means of already existing topoi* ("common places") which are nothing else than partially reusable generic libraries in a new context of application.

These two procedures seem to be at the basis of almost all methodologies of thematic knowledge acquisition (see, for instance, Vogel 1988).

The "dispositio" deals not only with the ordering of relevant themes in *sequenced configurations* but also, and even more specially, with the *rhetoric predicates* or the *acts of discourse* such as, for instance, the description, the narration, or the explication. The interesting point here is the fact that classical rhetoric not only furnishes us with rather systematic descriptions of these acts of discourse but also methods showing how we can elaborate them. In this sense, the heritage of classical rhetoric is relevant not only with respect to theoretical and practical purposes in the field of text understanding and text production (or generation) but also with respect to descriptive problems concerning the refinement and the elaboration of thematic context-sensitive reasoning procedures for KBS.

3) *Conceptual Analysis*

Conceptual analysis constitutes a common and general framework that encompasses not only linguistic descriptions but also non-linguistic ones as, for instance, thematic descriptions, descriptions of the visual language of expression, the description of the formal structure of a document or the description of the physical support of a document.

In this sense, it defines a descriptive strategy, in the sense of Dennett (1987), that relies heavily on a *theory of configuration,* which we will outline in the next section, as well as on the *three methodological assumptions concerning the activity of description,* which we have introduced in discussing succintly linguistic descriptions.

As such, conceptual analysis defines therefore a *common structure* of the different descriptions of the levels that constitute a document, of the context of communication, and of the life-cycle of the document and the context. In this sense, it is closely related to computer semiotics, as discussed by Hasle (1993).

SECOND PART:
CONCEPTUAL GRAPH THEORY AND FORMALIZATION

1) *The Notion of 'Graph'*

Let us repeat again the assumption that the "common structure" of descriptions of knowledge standards is defined –at least partially– by the following central notions, for which we have to provide explicit conceptual and formal theories:

- *(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 this section, we will try to give a very general account of these notions by the means of the conceptual graph theory developed by Sowa (1984). According to him, a conceptual graph is a finite and connected graph which possesses 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 (1984: 73).

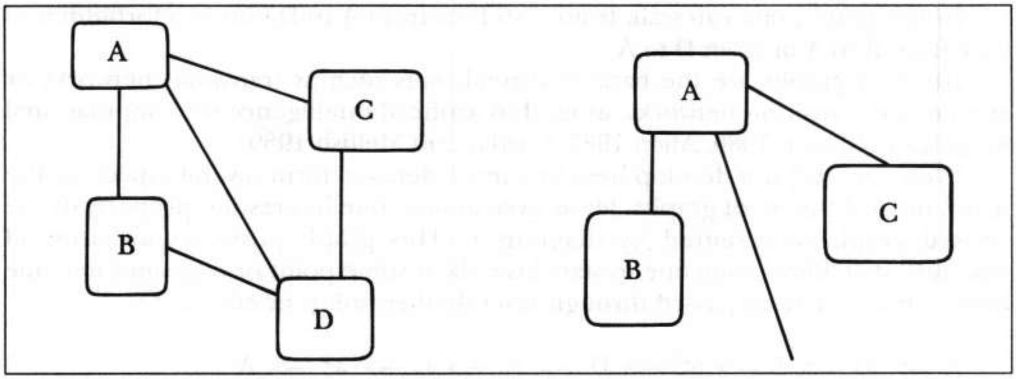
Conceptual graphs are based on the mathematical theory of graphs (Leszner 1980) that defines a graph G

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 "cross-cuts" 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 the product of two or *n* arcs.

Normally, a graph is represented by diagrams –a representation form which 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) is not a graph following the definition given above:

Diagram 1 Diagram 2



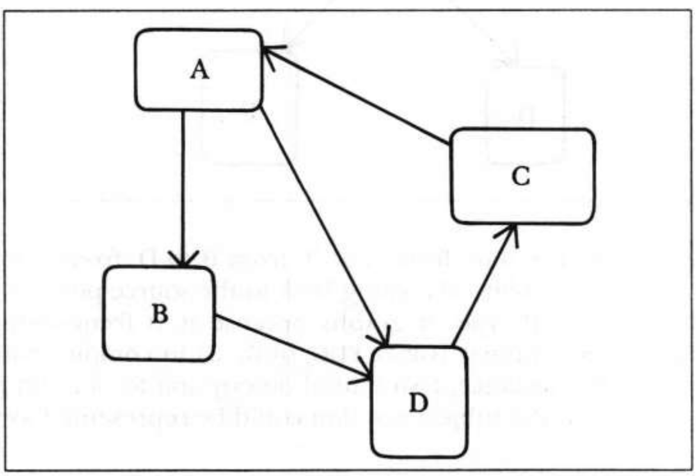
In diagram (1) all arcs are linked to edges whereas in diagram (2) there is one arc that has not an edge as its cutpoint.

Notice that the diagrammatic 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 "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 an *undirected graph* because the arcs which are linked to its nodes do not 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, on the other hand, possess arcs with an arrowhead which indicates the direction that one has to follow in order to walk through a graph.

Consider the revised diagram 1:



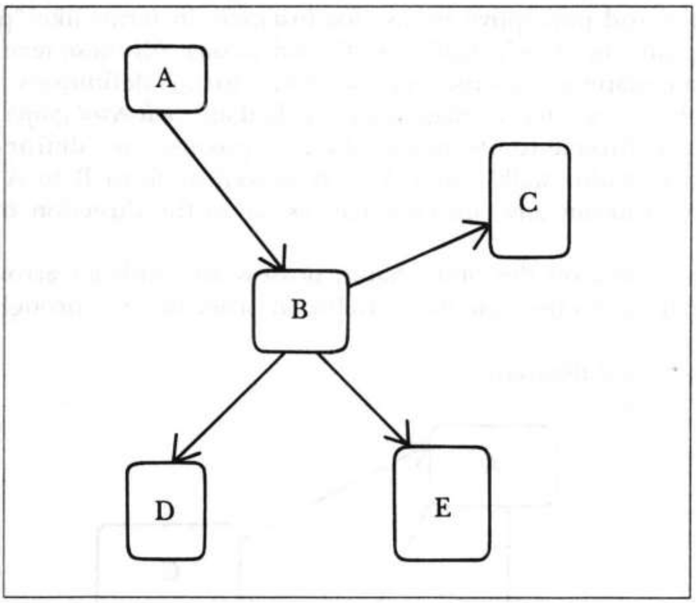
In this graph, one can walk from A to B or from A to D, but it is forbidden to walk from B to A or from D to A.

Directed graphs are the basis of formal tools such as transition networks or augmented transition networks, as used in artificial intelligence or computational linguistics (Nilsson 1980, Allen 1987, Gazdar and 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 one interesting property of the revised graph represented by 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 through several other points or edges, cf.:

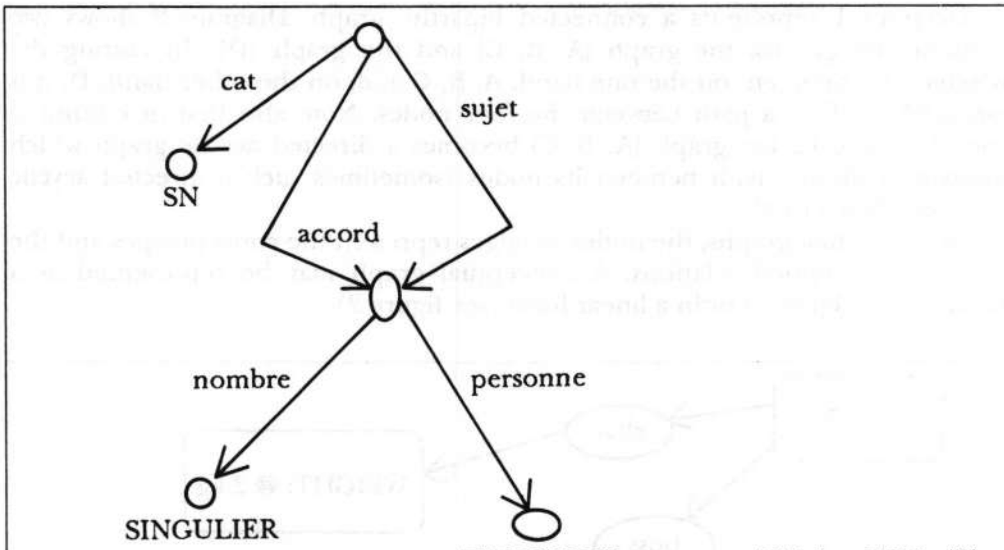
A —> a1 —> B —> a2 —> D —> a5 —> C —> a4 —> A

A graph that possesses such a structure is called a *directed cyclic graph.* A more constrained formal type of graph is the type of *directed acyclic graph,* which is a graph where cycles do not exist. Consider the following diagram:



In this graph, one can walk from A to B, from B to D, from B to E or from B to C. But there is no possibility of coming 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:



(Shieber 1990: 42)

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 do not receive a special label.

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 theory as the quoted theories used in computational linguistics.

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

Diagram 1

Diagram 2

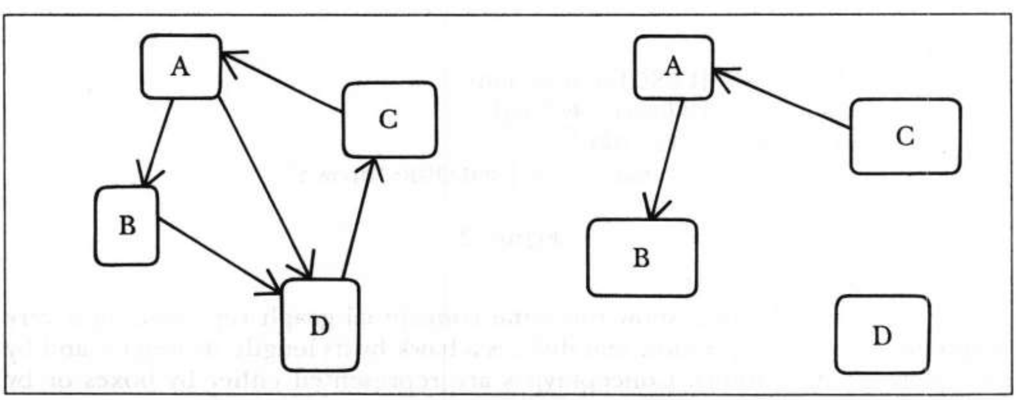


Diagram 1 represents a connected bipartite graph. Diagram 2 shows two disconnected graphs: the graph {A, B, C} and the graph {D}. In cutting the directed arcs between, on the one hand, A, B, C and, on the other hand, D, it is impossible to find a path between the four nodes. Note also that in cutting 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).

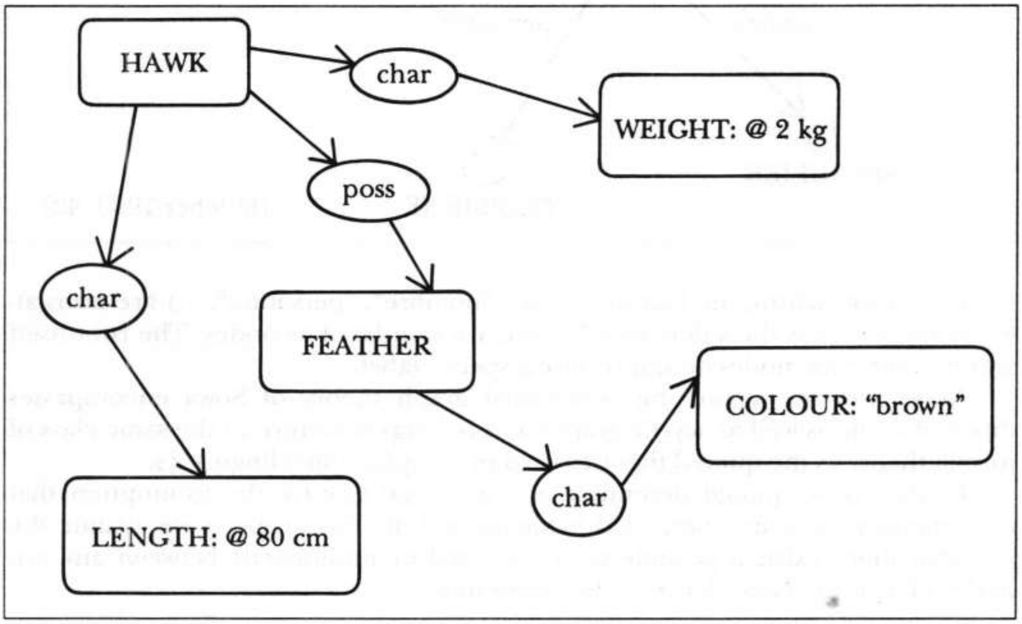


Figure 1

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

Figure 2

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 into two parts –a left one and a right one– that are separated by a colon: [:]. The left part receives the generic concepts or concept-types whereas the right one houses the referents or the range of values that can satisfy a generic concept or concept-type.

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 (x, y) 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.

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

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

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

See again the following linear transcription of the same graph:

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

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

An interesting feature of the linear transcription of a conceptual graph is the fact that it necessarily exhibits a certain point of view –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 nevertheless allow different points of view 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 necessarily presupposes the possibility of evaluating the truth-values of a description; otherwise, we would not be able to decide if we are dealing with several points of view of a same description or if we are dealing, on the contrary, with different descriptions.

2) *The Representation and Formalization of Configurational Descriptions by the means of Conceptual Graphs*

Let us now come back to the descriptive category "configuration". We already know 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 equivalency between a structural configurational description and the formal structure of conceptual graphs that enables us to directly translate a given descriptive metalanguage into 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: "Virgin Mary holding in her arms the crucified Christ"

the following conceptual graph corresponds:

[SCULPTURE: "statuette"] –
(char) <— [PERIOD: "gothic"]
(char) <— [MATERIAL: "wood"]
(char) <— [CHROMATICS: "monochrome"]
(char) <— [DATING: "14th century"]
(char) <— [MOTIF: "Virgin Mary holding in her arms the crucified Christ".

The equivalence 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 Φu is a formula determined by the following construction:

* If u contains k generic concepts, assign a distinct variable symbol $x_1, x_2, \ldots x_k$ 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 ith argument of the predicate be the identifier of the concept linked to the ith arc of r.
* Then Φu has a *quantifier prefix* $\exists x_1, \exists x_2, \ldots \exists x_k$ 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 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)
  PERIOD (gothic)
  MATERIAL (wood)
  CHROMATICS (monochrome)
  DATING (14th_century)
  MOTIF (saint_mary_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_mary_holding_in_her_arms_the_crucified_christ)

* the six monadic and the five dyadic predicates constitute together the body *u of Φ* that does not 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) ∧ CHAR (statuette, gothic) ∧ PERIOD (gothic) ∧ CHAR (statuette, wood) ∧ MATERIAL (wood) ∧ CHAR (statuette, monochrome) ∧ CHROMATISM (monochrome) ∧ CHAR (statuette, 14th_century) ∧ DATING (14th_century) ∧ CHAR (statuette, saint_mary_holding_the_crucified_christ_in_her_arms) ∧ 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:

∃x ∃y (HAWK(x) ∧ CHAR (x, 80 cm) ∧ LENGTH (80 cm) ∧ CHAR (x, 2 kg) ∧ WEIGHT (2 kg) ∧ POSSESS (x, y) ∧ FEATHER (y) ∧ CHAR (y, brown) ∧ COLOUR (brown)).

The possibility of mapping a configurational descriptive metalanguage into the representation system of conceptual graphs and the possibility of mapping conceptual graphs into logical formulae have three 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 a pragmatic point of view in (thematic, linguistic, ...) knowledge description, it is not –as it has been often argued– in contradiction with formally or logically 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 (concerning the interpretation of the correspondencies between "worlds" (domains of reference), models, and formal languages, see especially Pedersen 1993). What one formalizes 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 are 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 criticism of semantic or conceptual networks, especially concerning 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. It is only in logic that 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 out, one of the most simple ways 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 of mapping conceptual graphs in logical formulae is of great interest because it ensures their almost direct use in the form of structured objects, terms or clauses in logical programming languages. Nevertheless, the implementation of conceptual graphs is not bound to languages like PROLOG –it is only a historical conjuncture that has put them together.

3) *Partially Ordered Hierarchies of Configurations, Configurational Dimensions, and Configurational Functions*

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 greater or lesser degree of generality or specificity and which could be (at least partially) instantiated by some values in a given domain of reference.

Therefore, 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 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.

Configurational dimensions that are mapped into 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, 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 (1984: 82). For example, 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 bound, even if this is not necessarily true from a purely mathematical point of view. A bound 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 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 $\sum$ 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 not only can account for the formalism of directed acyclic graphs as used in computational linguistics but also makes 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 presupposition (complementarity).

Let us assume $\sum$, $\{\ \}$ 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 other 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.: $\{x \mid x \in \Sigma \text{ and not } x \in S\}$).

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 the approximation of two given dimensions in a given configuration.

In other words, the theory of partially ordered hierarchies permits the explicit performance of several fundamental types of operations not only on description of thematic knowledge but also on descriptions of linguistic or non-linguistic (visual, ...) knowledge or 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 the 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 the several modalities of the 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 in order for using them in knowledge representation.

The first one consists 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, the relation of "agentivity" may be solely defined by the fact that one configurational dimension is at the source of the existence of another 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, or again no matter if the second configurational dimension describes a (physical or mental) process, a generic activity or 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 consists, contrarily, in the definition of subsets of more specialized configurational functions that constrain, indeed, to a greater or lesser extent the identity of the 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 does not 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 localization in space and time in more and more specified relations that take 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 adequate 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 assembly of independently existing entities via some relations. Therefore, 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.

Let us mention only that the theory of partially ordered hierarchies can be applied, too, to sets of whole configurations represented by graphs that permit us to distinguish them with respect to their specificity, generality, or their proximity (Sowa 1984).

4) *The Recursive Definition of a Set of Configurations*

Let us take 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 which is claimed at the beginning of a crisis and some condensed proposition-like descriptions that label 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. As in the structural analysis of folk tales, the named interaction pattern PHYSICAL-CONTROL could be decomposed in a series 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 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 and Abelson 1976) accounting for the fact that the evolution of a crisis 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 complete account of all possible interaction patterns and named plans –this is not even 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 a given knowledge description to be completed or modified.

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 series of state-descriptions that succeed one another or that are combined with more constraining relations like those that define counterfactual patterns, conditional patterns or probability patterns. On that level, it would also be possible to define several variants of a typical interaction pattern.

These different levels and components of the description of an object form –informally speaking– a huge and complex thematic configuration composed of 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 problem of the *representative set(s) of* –in our case– *thematic configurations.*

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 should instead look for the rules that permit us to generate such a representative set of configurations, to introduce new information in a given set of configurations as well as ensure that a given set of configurations conforms to a certain point of view or context. If we want to elaborate a descriptive model of a knowledge standard that conforms 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.

In order to start a more systematic investigation into 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)— [ARCTIC_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 a set of canonical thematic configurations. The first graph stipulates that a bird is characterized by its (general) colour, its weight and its size. The second graph asserts that a bird is "composed" of body-parts that are characterized by a shape. The third graph asserts that the feathers are localized by a body-part and that they are characterized 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 arctic 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 a 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 colouring of feathers, and so on. This fact does not represent an inconvenience because, as we have already confirmed and as we will see later on, new information or more pertinent information could be introduced in the canonical basis, as derived graphs or 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, would not be interpreted as a well-formed graph given the fact that there is no information in the canonical basis that stipulates that a bird is characterized by the dimension "metal". As in generative grammar, canonical graphs impose *selectional constraints* which permit us to distinguish between arbitrary and meaningful graphs.

From a pragmatic point of view, the canonical basis of graphs introduces some fundamental assumptions concerning the *level of 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 here is how to handle these changes –a problem which claims a theory of epistemic revision, in the sense of Gardenfors (1988) or in the context of a game-theoretical semantics (Hintikka and Kulas 1985).

There are *four canonical formation rules* for deriving a 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 to 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:

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

[BIRD: x] ===(is restricted to)===> [STERNA] ===(is restricted to)===> [ARCTIC_TERN] ===(is restricted to)===> [ARCTIC_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 characterized by its colour, its weight, its size and it is "composed" of body-parts that are characterized by their 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 bird or to some concrete specimen of a given sub-species. Let us consider the following graph w:

[ARCTIC_TERN: "leslie"] <—(char)— [COLOUR: "white"]
(char)— [WEIGHT: "12 p"]
(char)— [SIZE: "80 cm"]
(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 arctic 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 unspecified.

Now let us see how we can derive this conceptual graph from the canonical basis. There are three principal phases:

1) There is a first process of derivation leading from the first, fourth and sixth canonical graph g1, g4, and g6 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)— [ARCTIC_TERN]

r: [ARCTIC_TERN: "leslie"] <—(char)— [COLOUR: "white"]
(char)— [WEIGHT: "12 p"]
(char)— [SIZE: "80 cm"]

This process requires the following operations:

i) join between the first and the fourth graph on the position of [BIRD] (graph i);

ii) restriction of graph i to the concept [STERNA] (graph ii);

iii) join of graph ii with the sixth graph on the position [STERNA] (graph iii);

iv) restriction of graph iii to the concept [ARCTIC_TERN] (graph iv);

v) restriction of the generic concept [ARCTIC_TERN) in graph iv to an individual concept [ARCTIC_TERN: "leslie"] (graph v); and

vi) three repeated restrictions in graph v that relate the referent "white" to the generic concept [COLOUR], the referent "12 p" to the generic concept [WEIGHT], and the referent "80 cm" to the generic concept [SIZE] (graph r).

2) There is a second derivation process (which is almost identical with the first one) 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]

g7: [BODY_PART] <—(is_a)— [HEAD]
              (is_a)— [BODY]
          (is_a)— [WING: { * } @ 2]
       (is_a)— [TAIL]
    (is_a)— [LEG: { * } @ 2]

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

The second derivation process requires the following operations:

a) join between the second and the third canonical graph on the position of [BODY_PART] (graph a);

b) join of graph a with the seventh canonical graph on the position [BODY_PART] (graph b);

c) repeated restriction of the concept [BODY_PART] in graph b to the two proper subtypes [WING: { * } @ 2] and [TAIL] (graph c); and

d) repeated restrictions that conform the generic concept [COLOUR] in graph c to its corresponding referents "white and blue" if it is localized on the wings, "white" if it is localized on the tail.

3) Finally, there is a join between graph r and s and, simultaneously, a restriction of the concept [BIRD] in s to the individual concept [ARCTIC_TERN: "leslie"] that produce the graph w.

The thematic configuration represented by the graph w constitutes a set of canonical and derived descriptions by the means of which we assert some physical aspects of a particular arctic tern called Leslie. Even if we have not given a direct account of the description of the physical aspects of this bird, we are able 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 (*lato sensu*) in artificial intelligence (Cox 1987, Masimi et al. 1989, Ferber 1990, Rumbaugh et al. 1991).

The practical idea that underlies this vision is to construct a relatively small set of *general* (and *generic*, see below) configurational descriptions called *"libraries"* that are reusable 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 the information from a knowledge source which is relevant in a given context of application. Knowledge description by the means of configurational entities and knowledge representation and formalization with conceptual graphs seem to us to be the appropriate way to realize this idea (see also Thayse 1989, Stockinger 1993).

As Sowa has pointed 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 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 specific than the configurations from which they are derivable. As Sowa has shown, the theory of partially ordered hierarchies also applies to entire sets of conceptual graphs and not just to concepts and conceptual relations (Sowa 1984: 96-103).

5) *Generalization and Deduction of Configurations*

Given the formal possibility of defining a partially ordered hierachy 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 us to elicit more general knowledge from more specific knowledge.

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 type(πc) $\leq$ type(c). If c is individual, then referent(c) = referent(πc).
> For each conceptual relation r in v, πr is a conceptual relation in πv where type(πr) = 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)— [ARCTIC_TERN]

r: [ARCTIC_TERN: "leslie"] <—(char)— [COLOUR: "white"]
(char)— [WEIGHT: "12 p"]
(char)— [SIZE: "80 cm"]

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

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

* The projection of g4 in g6 is g'4: [STERNA] restricted to the proper sub-type [ARCTIC_TERN].

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

* The projection of g1 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 latter and must therefore "contain" it as a subgraph that is necessarily more general than the entire graph. Projections of any more general graphs into 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 viceversa) nor necessarily unique (there may be several different projections from one more general graph into a more specialized graph).

As Fargues and Catach (1985) and Fargues et al. (1986) have pointed 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 et al. 1986: 77).

6) *The Definition of New Configurations, Configurational Dimensions, and Configurational Functions*

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

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

For several years, a lot of formal research has been done in the field of dynamic and partial models, especially in the so-called non-standard logics and in formal semantics (Barwise and Perry 1983, Hintikka and Kulas 1985, Gardenfors 1988, Martin 1987, Nef 1988, Gregoire 1990). Almost all of this research tries to give a formal account of changing circumstances or contexts, of particular points of view or (mutual) epistemic states that influence the validity of a description of some object that itself evolves in time and in interaction with other objects.

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

We do not have time here to discusss more systematically the interest of these new theories for knowledge description and representation; we must restrict ourselves to a relatively 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 for modifying a given knowledge base of conceptual graphs representing a set of (thematic) configurations:

1) the introduction of new conceptual graphs into 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 context 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 onto a graph u.

Let us take an example. 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 information about a particular type of feather like, for instance, the remex, the tectrix or the down of a bird.

In order to satisfy such a request, there is the possibility of defining a new concept or a new (thematic) dimension which –when unfolded– constitutes an entire graph representing new and appropriate 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 may also be characterized 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 onto which the abstraction is mapped and "c" specifies the formal parameter that links the new concept type to a generic concept in the body.

In our example, "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, Thayse et al. 1989).

The procedure of type-definition can be extended to the definition of new conceptual relations. This is an interesting possibility given that from some hypothetically basic thematic functions we can systematically construct even more complex functions which 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 organization of these dimensions. This vision is near to that which prevails in localistic case-theory (Gruber 1976, Anderson 1971, Jackendoff 1983, Descles 1985, Petitot 1985, and others) 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] (Sowa 1984: 114).

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

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

by the graph v:

v: [EAT]——(agnt)——> [PERSON: "paul"].

There is much interest in using the procedure of the definition of new (thematic) functions represented by conceptual relations. As we have already mentioned, 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 the creation of an uncontrollable open list of functions or relations as 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 close to the philosophy and epistemology of gestalt theory and structuralism.

The strategy of defining even more specific and specialized functions using certain basic functions or relations would seem 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 we 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 planning.

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 example 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 an 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 and 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" are two of the most fundamental operations in human discourse-activity, no matter if this activity has a specialized technical or scientific character or if it takes place in our everyday life.

In this sense, the operations of condensation and expansion give 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 embedded.

7) *The Attunement of the Validity of a Configuration to a Context*

The procedure of definition of new concept types and conceptual relations behaves, quite obviously, like the Porphyrian type of definition that states necessary and sufficient conditions asserting that "definitio fit per genus proximum et differentiam specificam".

But it is clear, too, that this type of definition underestimates the role of the context in which a definition is valid as, for instance, Coquet 1984 and Eco 1984 have argued from a semiotic point of view. Nevertheless, the Porphyrian type of definition is necessarily valid even for so-called context-dependent and prototypical definitions. It stipulates only what must be held to be true in a given context. Without this basic principle, no communication would be possible.

In accordance with Putnam 1975, Eikmeyer 1983, Martin 1987 or Lewis 1973, this principle can be applied only given a certain context, a certain point of view, a certain period or a certain place. As Barwise puts it, "an informational situation s (is factored) into two parts, the representation S and its embedding circumstances c" (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 points of view ("epistemic states" (Gardenfors 1988) or "univers de croyance" (Martin 1987)) concerning an object of reference. The several points of view can but must not necessarily be incompatible.

Thus, our statuette in the Louvre can be "seen" and interpreted by a simple tourist, by a historian of art, by a sculpturer, by a specialist in Christian motifs, by a restorer of ancient objects, and so on.

We have 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, there does not exist any common subpart at all and the two descriptions are not conflicting but incommensurable.

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

These 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 points of view and contexts *which have all their own canonical basis "containing"* the relevant but not globally true (thematic) configurations.

We meet here 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 bases 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 of formation and the operation of projection constitutes one component of a general "communication protocol" between the actors of a community.

From a formal point of view, the procedure of schematic definition is equivalent to the procedure of the Porphyrian definition. Each schematic type definition is a monadic abstraction λc u which is written as follows:

schema for t(c) is u.

Given the fact that there are several points of view 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 $\{\lambda a_1 u_1, ..., \lambda a_n u_n\}$ 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 example of a schematic cluster that represents three points of view of an arctic tern: the first one concerns its physical aspects, the second one concerns its alimentation, and the third one concerns its reproduction.

1) schema for ARCTIC_TERN (x) is

[STERNA] <—— (char)—— [COLOUR: "white"]
(char)—— [WEIGHT: "12 p"]
(char)—— [SIZE: "80 cm"]
(poss)—— [WING: { * } @ 2] <——(char)—— [SHAPE]
(loc)——> [FEATHER]
(char)—— [COLOUR: "white_and_blue"]
(poss)—— [TAIL] <——(char)—— [SHAPE]
(loc)——> [FEATHER]
(char)—— [COLOUR: "white"]

2) schema for ARCTIC_TERN (x) is

[BIRD] <——(agt)—— [ALIMENTATION]
(obj)——> [EDIBLE_OBJECT: {crustaceous, seaweed, *}]

3) schema for ARCTIC_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 disputable they, nevertheless, show the interest of the creation of such schematic clusters. Each schematic definition is based either on a canonical graph or a graph that is derivable from a given canonical basis. The first schematic definition, for instance, is based 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 bases that constitute some fundamental knowledge assumptions concerning, respectively, animal alimentation and reproduction.

In this sense, the 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 bases 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 to its nutritional habitude.

The strategy to produce schematic definitions is indeed a very interesting one for the elicitation and description of several knowledge standards. A knowledge standard is necessarily limited to one or several points of view which are assumed by an actor. This is not only true for thematic knowledge but also for linguistic (lexical and grammatical) knowledge, visual knowledge or knowledge concerning the (formal and physical) organization of a document.

As far as the description of lexical knowledge is concerned, it is intuitively clear that the meaning of a "word" depends highly on the contexts in which it is used as well as on a presupposed semantic theory to which it refers. The word "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. By the means of a schematic type definition, the several meanings of the word "coeur" will be broken up following several prominent points of view (viz. the point of view of physiology, the point of view of alimentation, the point of view of problem solving, ...), and for each one there will be coined an appropriate lexical description.

As a "communication protocol" between these several meanings, one can propose either a rather generic description, like in structural semantics –i.e., "coeur" is a "central organ"–, or an intuitive or "experiential" description, as it prevails in current cognitive semantics (Lakoff 1987).

We have already mentioned several times the notion of contexts in stipulating that it has to be taken into account during the description and modelization of knowledge. It is, indeed, highly artificial to speak about (thematic) configurations without taking into account the "environment" in which they take place and with which they interact. Furthermore, it does not make much sense to introduce schematic definitions without making further investigation into the context for which a schematic definition is provided.

There are several particular problems concerning the description of contexts. The first one consists in the difficulty of identifying a context or a type of contexts and of distinguishing them from other context 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: 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? For instance, the description of the statuette in the Louvre taking into account the point of view of the historian of art, is it sufficiently relevant for the point of view of a specialist of Christian motives, for the point of view of a restorer of ancient objects, for the point of view of a sculpturer, ...?

Another problem concerns the canonical description of the context, viz. a kind of hypothesis by the means of which we approach and analyse this notion. Following several investigations in formal pragmatics (Bartsch 1986, Galmich 1991), we assume a little set of basic dimensions that constitute the coordinates following which a context could be characterized. Among these dimensions we count the following ones: [ACTOR], [POINT_OF_VIEW], [TIME], [SPACE], and [ASSERT] (Ploteny and 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 (1971) or Lewis (1973).

The important point here is that the quoted dimensions could be unfolded into entire graphs or a set of graphs. In this sense we are able to account for 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 mentioned the fact that a context is describable as a (thematic) configuration that dominates another configuration (or a set of other configurations). Therefore, the referent of the configuration describing a context is a dimension, relation or a whole configuration and neither an object "in the world" nor a linguistic or visual entity.

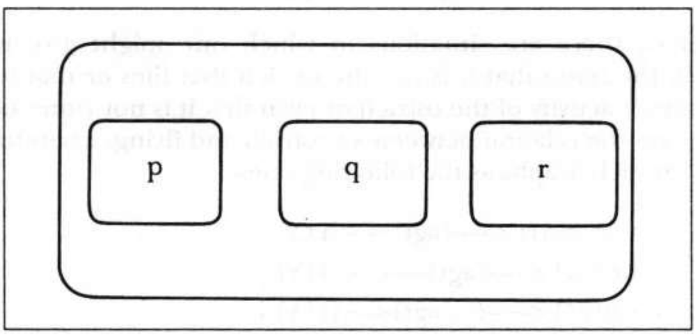
The representation and formalization of contextualized configurations (viz. of configurations that have as their referent another (set of) configuration(s)) are handled by nested graphs:

> Let p be a concept of type PROPOSITION whose referent is the set $\{u_1, ..., u_n\}$ of conceptual graphs: [PROPOSITION: $\{u_1, ..., u_n\}$]. 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).

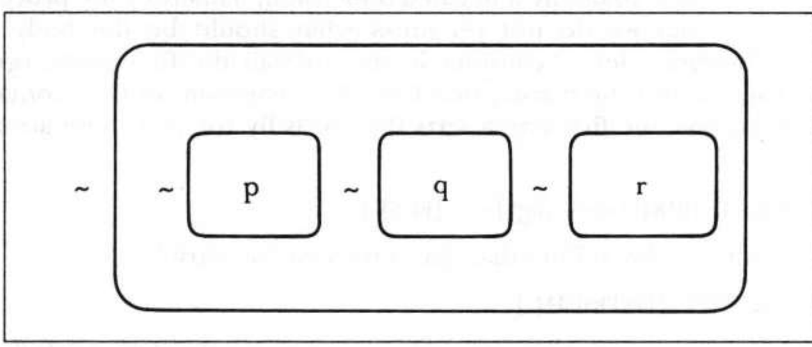
Our label [ASSERT] corresponds to the label [PROPOSITION] quoted by Sowa and sometimes used in linguistics, where a distinction is made between the propositional content of a sentence and its modal frame ("modal" is used in a very wide sense which is more or less equivalent with the notion of "enunciation" in pragma-linguistics or 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 (for a more detailed discussion on the relationships between Sowa's conceptual graphs and Peirce's existential graphs, see the very interesting paper of Orstrom (1993).

The several Boolean operators defined in 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 $-(-p \wedge -q \wedge -r)$ and can be represented as follows by the 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:

— [ASSERT: {— [p] — [q] — [r] }]

In generalizing the technique of nested (negative) contexts and in assuming that there are n levels of contextual nesting, we are able to take into account the partial specificity of contextualized (thematic) configurations that can partially overlap with other context-dependent configurations 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 take into account the problem of the scope of negation discussed by Sowa (1984). 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 does not fly would be represented as follows:

[ASSERT: — [[OSTRICH] <—(agt)— [FLY]]].

Nevertheless, there are situations in which one might give more precise information in the sense that it is not the ostrich that flies or that it 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 deal with such graphs as the following ones:

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

In order to deal with these 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 already know 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 in more detail the first graph (graph a) asserting that it is not the ostrich that flies. This assertion, in fact, contains two different assertions: the first one asserts that birds fly (or that there are animals that fly):

i) [ASSERT: [BIRD] <—(agt)— [FLY]]

and the second one that refutes that that 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 now also know which is the "body" that we need for the definition of a negated dimension represented by a negated concept:

type ¬ t(x) is [T: *x], ¬ [[t: *x]]] (Sowa 1984: 147)
or:
type: ¬ t(x) is [ASSERT: { [T: *x], ¬ [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.

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

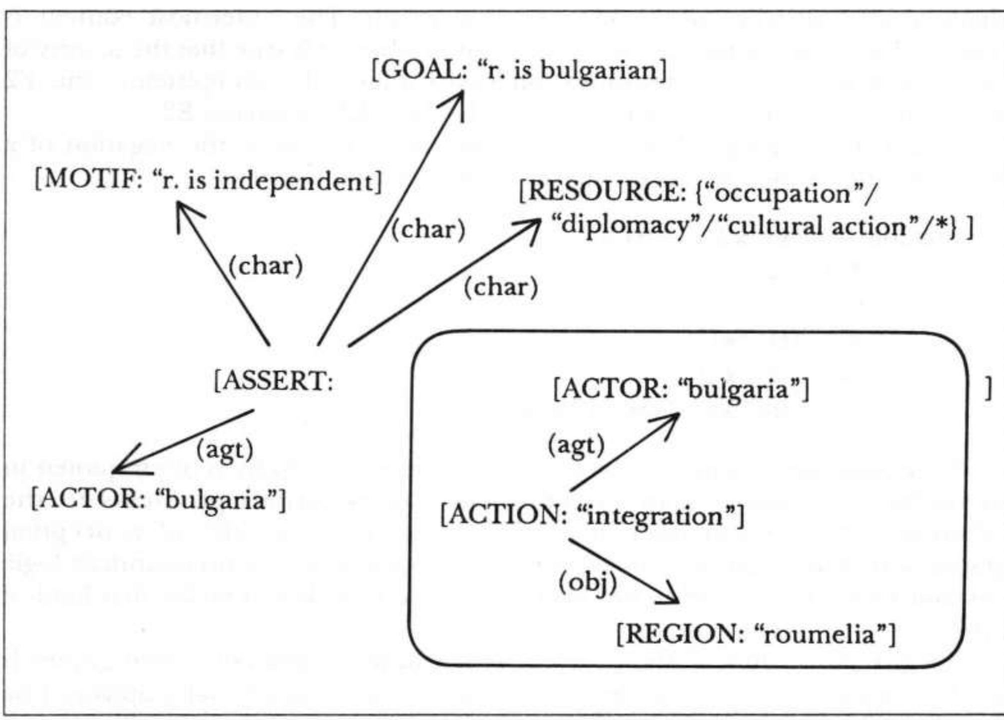
relation ¬ r (x1, x2, ..., xn) is
    [t1: *x1] [t2: *x] ... [tn: *xn]
    ¬ [(r)–
        <—— [t1: *x1]
        <—— [t2: *x2]
        <—— [tn: *xn]] (Sowa 1984: 148).

Note, that the example of the inability of the ostrich to fly is often quoted in specialized literature as an example that causes serious problems to the inheritance mechanism used in partially ordered hierarchies of conceptual graphs, structured objects, frames and so on. A special type of non-standard logic –default logic (Reiter 1980)– has been developed that should tackle that kind of problems.

To give an account of the problem of negation in terms of nested graphs is not incompatible with default logic given the fact that conceptual graphs can be "translated" in the language of FOPC which can be attuned by special operators to the requirements of default logic. But the objectives that we want to pursue here are to take explicitly into account pragmatic or epistemic factors that intervene in the revision of a given "theory" of some object of reference or, in other words, to elaborate a more pragmatically oriented conceptual and formal framework of the "negotiation" of the validity of knowledge standards between actors that have to find a solution (a new "equilibrium") for the epistemic conflict which opposes them (Stockinger 1992, Ploteny and Stockinger 1993).

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 example of the description of actions and plan-structures in conflicting situations opposing two or n actors. A scenario representing such situations of conflict must be composed of at least three major types of configuration: a first type of configuration that describes the manifested actions that are relevant for the evolution of a given crisis, a second type of configuration that describes the planning of the manifested actions as well as the goals that are pursued by an actor, and a third type of configuration 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 types of configuration, we have a nested representation that looks as follows:



This representation refers to a (very simplified) description of the basic intention of Bulgaria pursued during the first war between Bulgaria and Serbia (1885). The description asserts that Bulgaria pursues a basic action which is the obtaining of Eastern Roumelia –a region around Plovdiv in modern Bulgaria– and that is determined by a plan that the actor Bulgaria has at its disposal. The plan itself exhibits the motives, goals and resources 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 of "simulating" the selection and the decision of a particular basic action given a "pool" of possible actions that constitute the "resources" 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 motives 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 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 conflicting situations that are closely related to those produced in the theoretical context of game theory (Schelling 1960).

As we have already stated, knowledge description and representation could be effected 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 which characterizes conflicting situations. Like Schank and Abelson (1976), one could decompose, for instance, the basic action into a series of more particular actions which together realize the basic action. For instance, the first Serbo-Bulgarian war could be decomposed into 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, 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 simplest cases, "simulate" the progressive realization of a principal or basic goal by the means of motivated choices 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 explanatory attempt of what Schank and 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, once again, emphasize that it is an appropriate tool for the representation and formalization of descriptions that have to take into account what is now called "multi-expertise", that is to say, the existence of different and divergent knowledge standards in a given domain of reference.

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