Multimedia objects into knowledge representation for communication

José A. L. Brugos
Universidad de Oviedo
Departamento de Informática
Brugos@epsig.uniovi.es

Introduction

A book quote of Norbert Wiener's *Cybernetics and Society* (1950) poses problems which are today even more actual that in the moment they were put forward by Wiener : "*This book maintains the theory that society can only be understood through the study of messages and the communication facilities this society has. Moreover, in the future, messages sent from men to machines, from machines to men and from machines to machines will play an ever increasingly important role*".

We are going to deal with one subject which is closely connected with the topic of iconic representation: knowledge representation of abstract concepts and concret objects (multimedia objects), under denomination of the distribute classes/sets and collective classes/sets. It is a question of presenting a method of knowledge representation, based on Semantic Networks (SN), which extends its use to objects such as images and otherones, and that we name *perceptive objects*, and which returns into the question of the inheritance problem of properties in such cases, allowing to introduce logical processes of deduction. The foundations of the difference between set/subset and whole/part are studied as classical relationships that require a careful and specific treatment to avoid the "paradox of inheritance properties" between different objects, and that, as a consequence, they do not support it in the same way. The whole/part relationships are more complex than the set/subset relationships, and this is the reason why a complete theory about them has not been developed, although it has come to the attention of logic researchers. Something similar has occurred in the case of relation theory, which has been later formalized. As for the whole/part theory it was the Polish logician Lesniewski who dedicated a very special attention to his Mereology, or part's theory, as collective set theory, which is the main part of his ontological system. Lesniewski arrived at it motivated by his research on mathematical foundations and his personal interpretation of the so called paradox of Russell in the set theory origins.

This aspect of **multimedia knowledge representation** follows the classic principles of iconic language, that has its roots in the thought of Ch. S. Peirce (logic theory of signs). For Peirce the representations are **icons, index and symbols** (c 274), and " *the only way to broadcast live an idea is by means of an icon*" (c 278), and "*a percept is an image or moving picture or other exhibition*" (v 116, # perceptual judgment, Collected Papers, vol. VI, p.73), and, finally, "*our perceptual judgments are the premisse for us and these perceptual judgments have icons as their predicates in which icons Qualities are inmediately presented*" (v 6, Collected Papers, vol. VI, p.76), and in the last resort, in Platonic ideas. Here, protoimages are understood as a source of knowledge, recognized by semantics which the user spontaneous applies and by means of interpretation carried out by the system. This approach is very close to the concept script developed by Shank (conceptual dependencies), because it implies a standarised analysis and organization, and it emphasizes communication semantics. It also entails an agreement between system and user, as single and stipulated speakers. We take images as a means of knowledge representation (and not only as dates), following the guideline of the translation of knowledge already organized by the semantic networks. The translation process into multimedia objects adquires then prominence (and its special moment) inside the method.

Constitute a main aspect, in our approach, Relationships between perceptual and abstract (conceptual) objects, and especially whole/part relationships. This latter relationships (whole/part) are very complex and are difficult to formalize, as can be seen through the difficulties that researchers, throughout History, have found in cathegorizing them in a general way. Gestaltpsychology has made a relevant effort, with his paradoxical properties of independence and superadditivity (Ehrenfels), which later on under the concept of totality were applied to physics (Kohler) and to biology (Golstein). However the totality concept covers every domain of the sciences with different meanins. These difficulties have been made evident the spanish philosopher Gustavo Bueno in his writings, for example, "Todo y Parte" (1988) and "Estructuras Metafinitas" (1955). Other approaches refer whole/part distintion to an ontological-formal theory, as Husserl did in Logical Investigations III (1900), Leonard&Goodman (1940), and today N. Guarino, A. Artale, and other writers. However, Gustavo Bueno considers that a reductionist vision of the concept (of whole) has been performed, and that we must return to an internal decomposition of components of its definition, that is, to the analysis of the unity and multiplicity, and to the applications of each one by means of analysis and synthesis, supposing that in this definition such components are considered as if they were simple and univocal. We must bear in mind that unity is, sometimes, of co-presence (neighbourhood, contiguity and interaction), but, at other times, it is isologic (equality and similarity), which do not exclude separability and distance. In both cases, unity is understood as previous to the division into parts and as the interrelationship of many parts. On the other hand, multiplicity means, for example, continous multiplicity (real numbers) in some cases, and, in others, discrete multiplicity, or dispersed, (the multiplicity of the series of natural numbers). Thus, in both cases, multiplicity could be understood as absolutely unlimited, or, otherwise, as limited by others, even if it could be infinite in itself (terms of the closed interval of the numerical straight line). As for the analysis or synthesis neither of them will ever be understood ever in the same way; sometimes, might be understood as a current binary relationship, but, in other times, totality will appear as a contradiction.

Our approach is developed within our method of representing instruction applications in multimedia environments, and is also founded within Intelligent Tutoring Systems (ITS) and Intelligent Computer Aided Instruction (ICAI), and the **user interfaces**. The multimedia objects may be separately communicated by means of cells, as in ATM systems (Asyncronic Transfer Mode), which they require to dispose of the suitable information layout for this packaging, codifying and compression required by current bandwith. The treatment of such objects will cooperate to guarantee the Quality of Service (QoS) which will benefit network users. We will name this method DMITS (Distributed Multimedia Tutoring System). From the DMITS we will provide the foundamental sketch focusing on the problem of knowledge representation used for these aims. Thus the main problem presented hier will deal with the organization of the Knowledge Bases, its formulation in the standard layout for its subsequent translation into the multimedia integrated objects through which knowledge will come to the users.

Knowledge Representation

The classical model of the Knowledge Representation Systems supposes a structure of knowledge based on hierarchical networks, where ***nodes*** are labeled by names of **concepts,** and ***arcs*** by names of **relationships**, such as, decomposing concepts in subconcepts, the current analysis do. Thus, the nodes-concepts are meant both by extensional classes or bottleneck of sets by means of inclusion set relationship ('⊆'), seating down a partial order. The classes are else meant as exemplifying and specializing types. In the past, this procedure sometimes leads mixing individual and classes, confusing the inclusion relationship ('⊆') with membership ('∈'), when the latter should be conformed only by leaves or terminal nodes for individuals. The **inheritance property**, by this interpretation, is based on the transitive property of inclusion, supposing that the classes are **distributed classes**, where every element of the class simultaneously has reflexive, symmetric and transitive relationships, i.e., that all the elements are equals in the class to which they belong, and, of course, may be replaced each other. Then, the classes are understood here as equivalence classes. In the classical approach, exceptions are dealt with means of noclassical logics: modals, nomonotonics, circumscriptions, etc. Distribute classes (specially intensional classes) are currently considered as equivalence classes, covering "universal concepts" (in platonic or nominalist sense).

The approach to **universal concepts** cross the logic history dividing logic authors too. Thus Platon objects to nominalist Anthistenes, Aristotle (inmanentism, moderate realism)) to both, the stoic nominalism to Plato and Aristotle. In Midle Age, platonist of Chartres, conceptualism of Abelard, aristotlelism of Aquino's Thomas, nominalism of Occam. Frege (*Uber Sinn und Bedeutung*, 1892) and Russell (*On Denoting*, 1905) encourage this discussion, and Husserl, Wittgenstein, Lesniewski, Carnap, Quine, Church and Goodman too. To the Aristotle's proposition "*existentia est singularium and scientia est de universalibus*" the answer of Quine was "*to be is to be the value of a bound variable*" (1953). Thus for us, universal concepts are monadic predicates, corresponding equivalence classes (whose elements hold reflexive, simmetric and transitive relations). For Aristotle, the features of universals are to be objective, ideal, predicable, intelligible, logic priority, and the features of individuals are to be substantial, concret, impredicable, contingent, chonological priority; however, the main characteristic of the universals is the ability to support qualities. (A. Joja, 1973).

A paradigm of this interpretation is the case of Semantic Networks (SN), understanding nodes as classes, i.e., one order predicates universaly quantified (the universals), and the directed arcs, relationships ('A Kind of': Ako), as binary predicates. **Inheritance is supplied by the implication**: to inherit properties is to follow on the string of implications following a path in a network. Thus, a Close Universe is established by nodes in a Semantic Network, and the rule base allows deduction by means of a more distinguished and general rule: the inheritance. The relationship of **'part of'** can be understood as a particular case of inclusion, or implication, with restrictions. Then too, the set of implications-relationships display through the Ako relationship the basic hierarchical structure of a SN, its skeleton, and for ribs the rest of relationships, the other properties.

If a SN traduces a Knowledge Base (KB) composed of **Production Rules**, the terms which are only at **condition-part** of the rules constitute the top nodes on the SN, and, at bottom, nodes staying only at **action-part** might be the leafs; in the middle, the other terms might be hierachically disposed with their associated properties.

However, when we introduce images in a KB, wherever might these be placed on a SN? If they are individual independent images, they can be placed on the leaves, and their behaviour might be like that of individuals. But more, if images are partitioned, then what could occur? Could they be hanging as a bunch of parts in partitioned image? What then will occur whith the inheritance? Obviously, this set of individuals are neither distributed classes nor simply individuals. It is known that parts do not have the same properties of the whole. Here, it is not suitable to consider the parts as subsets, by the Russell paradox, and, in general, for the Set Theory because aren't distributed sets for its elements. In other contexte and for different reasons, but on facing similar problems, Lesniewski had the idea of a Collective Set Theory, named **Mereology**, to research this issue.

This problem is general, but the case of images constitutes an important example, because images are basic objects of Multimedia and visual recognition, and images in a Data Base are a actual necessity. The Relational Data Base and its Entity-Relation Model, and, overall, Deductive Data Base are theoretically similars to SN, and they presuppose also to work with distributed classes, and since our problem is posed too.

Collective classes.

The term ***'collective class'*** is a **real name** (proper noun), which can not be reduced to a logical concept. So, the expression ***'class(a)'***, in a collective sense, is an object that really exists, that is composed of **all the objects from domain** of the objects **a**. Thus, if any domain of objects **a** is given, its collective ***'class'*** allows us **to get an object composed exactly of the objects appearing in the domain**, i.e., of the objects **a**. The indispensable condition for an which object **'kl(a)'** exists, is that the domain of objects **a** is not empty, i.e., that there exists an object **a**. The objects from which the collective class is composed may be disjunct, for example, in space or time. So, if there exists some objects whatever, for example, some bricks, the *'class of the bricks'*, in the collective sense, is an absolutely real existing object, composed of all the bricks no matter where they are found. And also, for example, the books that there are on my desk at this moment constitute an object which is the *'collective class'* of all the books that there are on my desk at this moment, whether they are in physical contact with each other or not.

'Collective class' has the following **properties:**

1) it is unique;

2) if it is the class of a single object, it is identical with that object;

3) the class of a class of objects is identical with that class. For example, for all A,B,a, if A is Kl(a) and B is Kl(a), then A=B; Kl(Julius Caesar) = Julius Caesar; Kl(Kl(bricks))=Kl(bricks).

The term definition: T2:'Kl'='collective class':

$$(Aa]\ \{a \in A \wedge (\exists B](B \in a \wedge (B](A \in a \rightarrow B \in el(A)) \wedge$$
$$(B]\{B \in el(A) \rightarrow (\exists CD](C \in a \wedge D \in el(C) \wedge D \in el(B))\} \equiv A \in \mathbf{Kl}(a)\}$$

taken in the following meaning. If an object **B** is the collective class builted with the objects **a** (in the extreme case **a** might be **B**) and a object **A** is a element of **B**, then **A** does not need to be any of the elemental objects **a** forming the given class, i.e., the object **B**. In the example whith books, we only consider books having printed pages, and if we suppose that not exists printed pages exist except those in the books. In this case, **B** is the collective class of **all the books** found on my desk at this instant, and the same **B** is also the collective class of **all the printed pages** found on my desk at this instant. Thus, the collective class has the property that *for all* **A,a,b,** *if* **A** is **Kl(a)** and **A** is **Kl(b)**, *then* **Kl(a) = Kl(b)**. However, it does not follow that the objects **a** must be the same objects **b**. From there we conclude that if an object **A** is an element of an object **B**, and **B** is the collective class of the objects **a**, then **A** is not neccesarily to be an **a**. Sofar, if **A** is the class of the books found on my desk at this instant and **B** is an element of **A**, then **B** is not necessarily a book, since **B** could be, for example, the fifth page of one of these books or the object being the collective class of all the illustrated pages contained in the books on my desk (supposing that there exists at least one illustrated page). In short, if **B** is an element of the object **A**, then **B** may be any piece whatever of **A**.

Part/whole Teory

We can distinguish between a theory of parthood (mereology) and a theory of wholeness (hology, which is currently afforded by topology).

The Classical or General Extensional Mereology (GEM) introduces:

A) a *proper-part-of* binary relation "⊂" as a strict ordering relation (trasitive, asymetric and finite), satisfying the additional principles:

a) Extensionality (Leibniz): two individual are identical ssi they have the same parts.
b) Sum: there always exists the individual composed by any two individuals.
c) Supplementation: if an individual x is a proper-part-of a individual y, then a different individual z exists which is the missing part from y ($y-x=z$, $\forall x \in y$).

B) a *improper-part-of* relation "$\subseteq$" as a partial ordering relation (transitive and antisimetric)

Despite the criticisms, the object centered approaches assume that the part-of relation is at least a partial ordering relation. However, there is problems (A. Artale, 1996). The underlying logic can be a standard first-order logic with identity. In addition, some mereological relations can be introduced followind the intended Parthood predicate: proper part, overlap, underlap, over-crossing, proper overlap and proper underlap. Also can be stablished the irreflexibility and non infinite descending chain, definig a lattice.

In my opinion, the proposal of Lesniewski (1916-1920) continues being the basis to extend Semantic Networks with a part/whole theory.

Lesniewski's axiomatic:

A1: transitivity of 'part of'

$$[ABC]\ \{A \in pt(B) \wedge B \in pt(C) \rightarrow A \in pt(C)\}$$

A2: the whole is not one of its parts
(*If an object A is part of an object B then the object B is not part of the object A*)

$$[AB]\ \{A \in pt(B) \rightarrow B \in \neg pt(A)\}$$

In the two following axioms occur these **terms:**

T1: '**el**'='element': $[AB]\ \{A \in A \wedge (A=B \vee A \in pt(B)) \equiv A \in \mathbf{el}(B)\}$

T2:'**Kl**'='collective class':

$[A\alpha]\{A \in A \wedge (\exists B]\ (B \in \alpha \wedge [B](A \in \alpha \rightarrow B \in el(A)) \wedge$
$[B]\{B \in el(A) \rightarrow [\exists CD](C \in \alpha \wedge D \in el(C) \wedge D \in el(B))\} \equiv A \in \mathbf{Kl}(\alpha)\}$

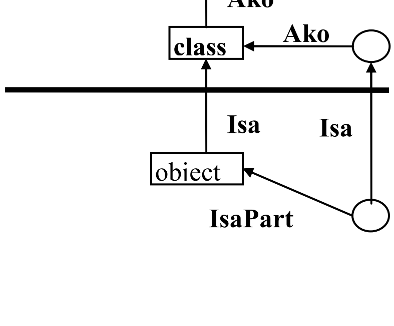
A3: the class of the collective classes **a** is ***unique:*** $[AB\alpha]\{A \in Kl(\alpha) \wedge B \in Kl(\alpha) \rightarrow (A=B)\}$

A4: there exists a collective class of **a**'s provided there exists at leat one **a** (i.e*., every collective class is unique and* ***not empty***): $[A\alpha]\{A \in \alpha \rightarrow [\exists A]\ A \in Kl(\alpha)\}$

One of the more noted consequences of this logic is that, although two collective classes could be equals, they must not have the same elements, for example, if **A** is the class of the books on a desk and **B** is an element of **A**, then **B** is not neccessarily a book, since **B** could be **the fifth page of one of these books** or the object that might be the collective class of all the illustrated pages contained in the books of the desk (provided that there exists at least one illustrated page, since a collective class can not be empty). For example, if the collective class *Spanish_Autonomies* consists of Catalonya, Euskadi, etc., i.e., Kl(Spanish_Autonomies) = {Catalonya, Euskadi, ...}, we can say that Catalonya is an element of this class, but not, for example, Lleida o Bilbo. In short, if **B** is an element of the object **A**, then **B** might be *whatever piece* of **A**. Anymore, botting collective classes, (Kl(Kl(a))), is the same collective class, for example, Kl(Kl(bricks))=Kl(bricks), i.e., that a collection of **a**'s is the same thing as a collection of collections of **a**'s, but the converse is not valid (a collection of **a**'s is not neccessarily identical to an **a**). A proof for induction might show that if the number of **a**'s is **n** then the number of collections of **a**'s is $\mathbf{2^n-1}$.

Our extended Semantic Networks

In our work and in the sketch that shows our approach to represent it, these problems are reflected by means of the relationships of what we call Perceptual Graph and Class/Conceptual Graphs, and, in particular, within the first one, which is where we apply the whole/part relationships.



The graph of concepts is organized, according to the method named RESMUL [Brugos, 93], starting from the concepts provided by the expert folow-up method, and giving rise to the "conceptual subgraph." This subgraph forms a nested semantic network of concepts, and it has three kinds of main node sets:
a) primary network (skeleton): based on the inclusion relationship of intensional classes (concepts); b) secondary network (body): based on the properties (attributes) of the concepts; and c) terciary network (aggregate): based on the part relationship. The entire graph can be inductively covered bottom-up.

The inclusion relationship is a relationship of the type "AKO" (A Kind Of), while the property relationship is a generic relationship, "Pro", that is specified according to every individual property. Objects of the perceptual subgraph can be considered as Collective (aggregate) sets [Brugos, 97]. The graph or network is divided in three basic subgraphs:

1) Conceptual Subgraph (intensional classes)
2) Class Subgraph (extensional classes)
3)Perceptual Subgraph (individual objects; instances)

For us, **Conceptual Subgraph** and **Class Subgraph** constitute distributive sets (equivalence classes, base of the universals), governed by the axioms of the classical set theory, and **Perceptual Subgraph** constitutes collective sets, governed by the axioms of whole/part theory, or mereology (Lesniewski). John F. Sowa has also appointed this possibility (1991), and later N. Guarino, A. Artale, P. Gerst, S. Pribbenow, and other researchers, have dedicated special attention to it from an ontological point of view; and, in particular, *Data and Knowledge engineering* review has published a special issue about this subject (1995).

The first level of graph contains (is labeled by) things such as global images, exemples of concepts, linked by means of *Isa* relation to conceptual graph (concepts). Moreover, all nodes of this graph are linked by means of *Isa* relations to the classes of the part-class graph. However, how is built class graph from latter?

Considering a generic node of the conceptual graph, denoted *Concept*, we will denote $\mathbf{IMG^1, ..., IMG^N}$, images corresponding to **N** instances of *Concept*. These nodes set out the top level of perceptual graph. Every one of these image nodes will hold so many son nodes as parts considered within every one of global images. In general, a $\mathbf{IMG^s_{i...j}}$, from decomposition in parts of global image of $\mathbf{IMG^s}$ (concept example).

A class graph is built from a perceptual graph, begining at the bottom. The nodes of the class graph contain equivalence classes, in the sense of equality of images, and the main realtionships between nodes are *Ako* and *Pro*. If $\mathbf{IMG^s_{i..jk}}$, $\mathbf{k=1,...,p}$, are image nodes corresponding to the bottom level of the perceptual graph, for every one of these image nodes we define the equivalence class made up of all the equal images to be considered. We represent this class as $\mathbf{\{imag^s_{i...jk}\}}$. Now we consider the joining of all these equivalence classes, $\mathbf{U^p_{k=1}\{imag^s_{i...jk}\}}$. Since in the perceptual graph every image node holds, as son nodes, images from the all the parts, i.e., those participating into knowledge, we can consider that $\mathbf{img^s_{i...j}}$ is just this set. Now we define a new node as the equivalence class of all images equal to $\mathbf{img^s_{i...j}}$ which we denote as $\mathbf{\{img^s_{i...j}\}}$. In this way, the image node $\mathbf{IMG^s_{i..j}}$ is related by means *Isa* realtion to a new node built in the class graph, $\mathbf{\{img^s_{i...j}\}}$. Moreover, this node is linked by means of *Ako* to every one of the son nodes (constituting a partition of the father node).

In this process we assume the following propositions:

a) No more outstanding parts exist in an image than defined by *IsaPart* relation within the perceptual graph.
b) The images determining *IsaPart* relation, for every node of perceptual graph, share no parts which can be considered as images.
c) It is possible to rebuild any image from parts defined in the perceptual graph.

Every node of the class graph, linked by means of *Isa* relation to an image node of the perceptual graph, contains equivalence classes, as subsets, corresponding to son nodes of image node. This hierachy induced by means of *IsaPart* relation from class graph provides an organization in which every node is the most suitable site to hold shared properties (attributes, not perceptual properties) for an image and its parts. Here the current procedures transmiting inheritance may be sought.

Collective set and Gestaltpsychology

Our hypothesis is that the seven laws of the perception in the gestaltpsychology are set out basically on the (mereological and topological) axioms of collective sets:

- Proximity (smaller distance).

- Identity (to tend for reunion in groups of equal elements).
- Totality (to tend to unify).
- Common destination or good courve.
- Common movement.
- Precision (Kofka) (good organization such as regularity, symmetry, totality, unity, equilibrium, maximun simplicity and conciseness).

This hypothesis has a base in close reasons to synthetic *a priori* judgements of Kant, in a similar way as Arbib writes:

"Lettvin et al. Conclude by saying that 'By transforming the image from a space of simple discrete points to a congruent space where each equivalent point is described by the intersection of particular qualities in its neighborhood, we can then give the image in terms of distributions of combinations of those qualities. In short, every point is seen in definite context. The character of these contexts, genetically built in, is the physiological synthetic a priori'. This view of 'the physiological synthetic a priori' will be highly relevant when we try to build upon Kant's idea of the schema in developing a theory adapted to the needs of late 20th century neuroscience" (Arbib, 1996, p.13). Following Arbib, perceptual schemas are those used for perceptual analysis, and not only does the schema determine the credibility of the hypothesis that the schema represents but also the parameters of properties such as size, location and motion, assembling other schemas as well.

References

Arbib, M.A., (1996), "Schema Theory: From Kant to McCulloch and Beyond". In Brain processes, Theories and Models, (eds. R. Moreno-Díaz and J. Mira-Mira), MIT, Press, pp. 11-23.

Bueno, G., (1955), "Estructuras metafinitas". Rev. de Filosofía, nº 53-54 (1955), pp.223-291.

Bueno, G., (1988), "Todo y Parte". Los Cuadernos del Pensamiento, pp.123-136.

Brugos, J.A.L., (1993, 1996), "RESMUL: An Idea for multimedia knowledge representation". In IV Las Palmas Seminar on Computer Sciences: "Advances on Neural Computing, Cast and Multimedia", CIICC, Univ. de Las Palmas, 12-19 Nov.1993; REMA, Rev. Electrónica de Metodología Aplicada, nº 1, 1996

Brugos, J.A.L., (1997), "Semantic Networks with Collective Sets". In SCI'97: Word Conference on Systemics, Cybernetics and Informatics, Caracas, July, 1997, Proc., vol 1, pp.72-79.

Data & Knowledge Engineering, 20 (1996).

Fabri, P., La svolta semiotica. Gius. Laterza & Figli Spa, Roma, 1998.

Husserl, E., (1976), " Investigaciones lógicas" (Investigación III). Rev. de Occidente, 1976 (1900/1913).

Joja, A., (1973), "La doctrine de l'universel chez Aristote". In Logic, Methodology and Philosophy of Science IV, North-Holland, pp. 904-919

Leonard, H.S., Goodman, N., (1940), "The calculus individual and its uses". J. Symbolic Logic 5, 45-55.

Peirce, CH.S., Collected Papers of Ch. S. Piece, vol V (Pragmatism and Pragmaticism), (eds.) Ch. Hartshorne and P. Weiss, The Belknap Press of Harvard University, Cambridge, Mass., 1974, pp. 73-77

Peirce, Ch.S., manuscript c. 1897 (c. 274, c 278)

Srzednicki, J.T.J. (ed.), (1984), "Lesniewski's Systems". Martinus Nijhoff.

Yazdani, M., Multilingual Multimedia. Bridging the language barrier with intelligent systems. Intellect, Oxford (U.K.), 1993

Yazdani, M., Barker, Ph (eds.), Iconic communication. Intellect, Bristol (U.K.), 2000.