Foundation of MITS: Integrating Intelligent Tutoring System in Multimedia

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ABSTRACT

After the proposals of J. Carbonell ("AI in CAI: an AI approach to computer assisted instruction", 1970) and, later, Ch. Dede ("A review and sinthesis of recent research in intelligent computer-assisted instruction", 1986), and others, incorporating AI in CAI (Computer Assisted/Aided Instruction) and constituting ITS (Intelligent Tutor Systems), a spectacular development of the multimedia environments and tools has ocurred. But one of the current problems of the ITS is obviously their integration in a multimedia environment, because Knowledge Base and interface moduls are principaly and radically changed by the use of images as direct knowledge. Moreover multimedia should be conceived for its uses within the new systems of data transmission and communication: nets and videoconferencing.

RESMUL (Semantic Networks in MULtimedia environments; Brugos, 1993, 1996) sought to focus on the representation problems and the inheritance property in Semantic Networks when concrete hypermedia objects are used, such as images, voice, text, etc. The special uses of mutimedia objects means readapting the Knowledge (Base) and Interface modules, etc., and to ploughing through the whole ITS. Then MITS (Multimedia Intelligent Tutoring Systems) seek to integrate ITS in multimedia lines by analysing and defining the functionalities of the multimedia objects: fixed images, text, voice and music, animations and video sequences. Multimedia objects are thus distributed analysing the functional use of every one for application The core of this approach is supported by the role of the images in concept formation and, in general, in communication processes, a kind of theatrical presentation, just as it is postulated by the cognitive psychology and iconic communication. Of corse the semantics of the images constitute a natural base for intuitive communication. The user analyses synthetic knowledge proposed inside a window system displaying mutually associated multimedia objects. Thus our approach restructures the classical modules (Knowledge Base, Interface, Pedagogical, Explicative, Adaptive Evaluation and Assistance) performing multimedia integration.

Our MITS propose a method for the:

a) knowledge adquisition and representation,
b) knowledge flow diagram to navigate
c) knowledge translation into multimedia objects
d) multimedia object integration
e) presentation
f) usability

Thus MITS also seeks to provide a method for designing and developing this kind of application and for incorporating it into nets and videoconferencing. The main virtue of MITS is that it serves as a theoretical foundation and a method that provides procedures for the three basic tasks of these applications: the acquisition and representation of information/knowledge, the translation of concept networks into multimedia objects and the integration of these multimedia objects.

This method continuous the original integration of AI in these kinds of systems, and the incorporation of the possible multimedia in AI.

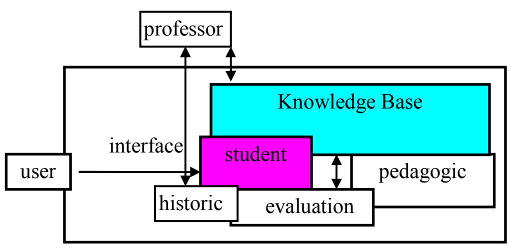
The results of this integration can be used in interface development, facilitating usability and adaptability for the user, the quick and natural learning on the part of users, the monitoring of data, the development of formative prototypes, etc.

Our method is being tested within a European project on integral logistic knowledge for small and medium-sized enterprises with CD-ROM, networks/Internet and videoconferencing support. MITS integration in videoconferencing suppose the realization of a frendly user interface for tutor, professor and students, Databases, horizontal and vertical communication, etc.

Key Words: Intelligent Tutoring Systems (ITS), Computer Asisted Instruction (CAI), Knowledge Representation, Semantic Networks, User Interface, Human Computer Interaction (HCI), Multimedia, Hypermedia, Hypertext, Distributed Multimedia, Machine Learning, Semantic Image Analysis.

1. INTRODUCTION

After the initial proposals of J. Carbonell ("AI in CAI: an AI approach to computer assisted instruction", 1970) and, later, Ch. Dede ("A review and sinthesis of recent research in intelligent computer-assisted instruction", 1986), and others, incorporating AI in CAI (Computer Assisted/Aided Instruction) and constituting ITS (Intelligent Tutoring Systems), a spectacular development of the multimedia environments and tools had been ocurred. But one of the



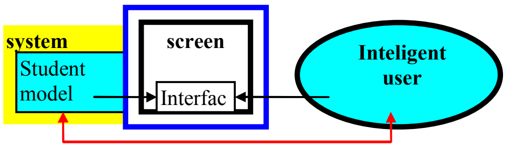
Sketch of ITS arquitecture

current problems of the ITS is obviously their integration in a multimedia environment, because Knowledge Base and interface modules are principaly and radically changed by the use of images like direct knowledge. Other media also participate in the domain expression, and they should be integrated in the system. Besides standalone multimedia there exists distributed multimedia that can support communication among users: networks and videoconferencing. The International Telecommunications Union (ITU) identifies four basic distributed services and applications: conversational, messaging, retrieval and distribution services.The ITS theory comes from the specialized Expert Systems, but substancially adding and adapting new modules: the student model, pedagogic strategies and acquired knowledge evaluation. The Knowledge Base has also to be reorganized and hierarquized according to the levels of the domain that it wants to transmit to the student. The Interface must also to be very natural and adaptive to the user.

Multimedia environments decisively influence the interface, but also the Knowledge Base, when using images as knowledge. The interpretation of concepts by means of images, and not only sentences (text), constitutes one of the greatest difficulties, but it is also one of their main tasks. Thus must need to assign functionalities to the media. We name this method MITS (Multimedia Instruction Tutoring Systems).

A proposition could be made concerning the relationships between Multimedia and the AI: *the human intelligent operations researched and parceled by the AI, can be highlighted and integrated when they converge with the multimedia historical research*. Before the AI came into being organized research (seminar of Darmouth, 1956), W. Bush had already conceived 'hypermedia' (1945). In the AI was Quillian (1966) who introduced associative pattern of the human memory in Semantics of the natural language, being inspired by Newell and Simon's research (1962), it has more than Problem Resolution. It is in the associative pattern where AI and Hypertext come together, what should be assumed by everyone hypertext parents (Bush, Engelbart, Neson). It is obvious that hypermedia = hypertext + sound, where at least one is a discrete medium and one is continuous. The term *hypermedia* rather focus on the non-linear aspects of multimedia interaction.

That is to say, multimedia accepts that the bases of human communication are ideas, in the Platonic sense of mental images (ιδεα: a certain abstraction of prototypical images to relate concepts). What best explanes this world of mental images in an interface is the so-called 'metaphor', i.e., a universe for user task in an application. We say icon langage, where a icon sustitutes what represents. Thus Ch.S. Peirce conceived the logic as signs theory (indexes, icons and symbols), i.e., semiotic [Peirce,74]. The space in which system and user communicate is a window in a screen.



Model of inteligent Student-user

The necessity of an user's model is patent in the communication systems based on the semantics (for example, conceptual dependencies and scripts: R. Shank, group of Yale) [Shank,77] , because such a pattern contains the interpretation that is expected from the user.

The knowledge acquisition pattern of J.R. Anderson (ACT * and then PUPS) represents a cognitive theory (the student's computacional model) for a productive model representation: a performance model and a learning model; where declarative and procesual knowledge is also interrelated [Anderson, 90].

2. FOUNDATION AND PRINCIPLES.

What we denominate cross problem, or status quaestionis, consists on the following:

in the acts of human communication images, text, voice, (indices, icons, and symbols) are interrelated, but in present day programming they are used like independent things (plasters), bound spontaneously in a parallel time/space by a programmer and interpreted by the user's natural semantics.

Our approach:

These 'plasters' of images, texts and sounds need a knowledge philosophy that bases their internal function inside the knowledge communication, that is to say to become elements of the knowledge structure but not only data. We call this philosophy (Ch.S. Peirce) [Peirce, 74] as the system-user's communication intuitive idea. The ***Ockam razor*** is our basic principle:

"To dialogue about what you see",

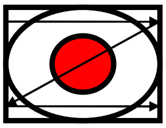
similar to Norman's ***appropiateness principle***: "*The surface representation used by the artifact should allow the person to work with exactly the information acceptable to the task: neither more nor less*" The first thing that an user captures are the images that he interprets immediatly (painting is the most direct art). The user contemplates the image presented on the screen perceiving its qualities and relationships among its parts directly (physicaly), and this perception is used as premises to create the 'icons' [Yazdani, 90] that represent the qualities of the image and primitive actions, as in Shank's scripts. An image is an **artifact**. **The screen works as well as a landscape of images in which the system and user will dialogue.** But the screen turns out to be the only communication frame and the image, its communication object that is respected by both (system and user).

An image is not good enough only to illustrate a dialogue, but rather it can begin it directly, with the additional advantage of behaving within a restricted context and a direct interpretation (pointed out by Comenius, s.XVII). In an image, besides a socratic pedagogy the user finds a syntax and an inmediate semantics that the system can exploit. A syntax because an image has a direct decomposition (partitions and relationships), and a semantics because it provides an idea, a context and some class names, and an dependent concept analysis. *Plato said that the butchers come to see animals as if they had colored the frontiers on their behalves: that is what the system needs to know, then - like Socrates - it will continue until the concepts (inside cathegories), linked by ideas.*

Some Postulates.

Postulate 0: the user is intelligent (an interpreting of signs, in the words of Peirce) and he tries to apply a spontaneous semantics to images.

1st. experimental postulate. The user observes a screen focusing on its center and spreading out his look centrifugally, and then he proceeds to travel it in the form of a Z, that is to say, from left to right and from top

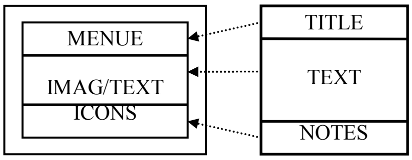


Visual journey for a screen

to bottom, following our current reading.

Corollary. The reading in Z, after the initial screen focalization, makes the user expect general information at the top, the characteristic content of the screen in the center, and actions to carry out in the bottom.

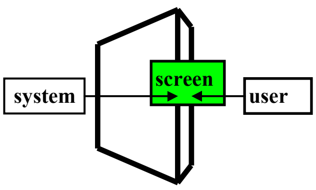
Note: this it is the current behaviour in a **screen layout**:



As can be observed, screen layout is the same as that of sheets.

2th experimental postulate.

The user first observes images and then text. Voice recognition demands a longe response time to that of image and greater concentration, therefore voice should have a function though highly imperative or for reinforcement (orders, observations, attention calls,

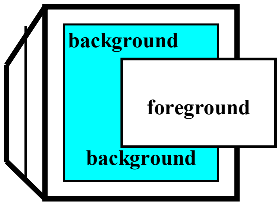


The communication system-screen-user's simplified outline

questions, statement-negations,...), i.e. subsidiary.

Some Principles.

1st. principle (this reminds the Turing Test):
The only means of communication between the user and the system is the screen.
All the information is therefore transmitted through the objects displayed on the screen; that it is the only semantic content in which the system and user must agree. And each screen contains an atom of knowledge.
Note: when we say that image is the only one, it is because sound plays a subsidiary role.
2th principle. As in Turing Machines, the previous screen collaborates in the interpretation of a particular screen. Between a screen and one previous view the differences are discriminated against (the new or specific) and the identities and analogies are identified (the constant or general), as when equivalence classes built ' universal concepts '.
Note: the knowledge is accumulative, and that the analogy is a primary abstraction outline. What is repeated is the general and the new actual is the specific (background and foreground screens). The properties of the background are inherited, they stay until a new one appears.



3.A MULTIMEDIA HISTORICAL PERSPECTIVE:
Multimedia Fenomenon

At the beginning of the Renaissence, with paper and printing the book is born: the industrial revolution of the information. Paper, being cheaper and more flexible than parchment, and the automation of the scribe's tasks (printing) because it transforms to the book into merchandise for a wide population layers.

Besides being cheaper and more abundant, because of its size and less sequential disposition, the parchment book or paper is already more quickly readable and governable than the papyrus roll that in turn regarding the mud and the stone. The *Tesaurus* (dictionaries) also advance in the organization (index) of the terms (nouns) relating them semantically through the concepts that they express. There is already a certain conception of semantic networks in the Thesaurus (as in a tree of nouns-concepts) that Leibniz tries formalizing symbolically by means of logical class and relationships. The goal of the MULTIMEDIA pioneers was economical storage, and the agile and flexible recovery of information in an electronic medium. For that reason it is said that they began the information electronic revolution. *Multimedia systems can be defined as capable of handing at least one type of continuous media in digital form as well as static media*.[Lu,96]

3.1. MULTIMEDIA PARENTS

1)**Vannevar BUSH** (1890-1974).

The **MEMEX (MEM**ory **Ex**tended) system was proposed by V. Bush in seminal paper '*What We May Think'* (1945; sketched in 1932,1933 and 1939), diffused by Ted Nelson in Literary Machines and by Microsoft. This paper served as inspiration for the investigators of the sixties, especially Engelbart and Nelson. Bush was an important hardware creator, becoming famous for their inventions, as the M.I.T. differential Analyser (1931). An outstanding contribution of Bush to Multimedia was their conception of a similar environment to WINDOWS in microfilms and their link blazers (freeways).

2) **Doug Engelbart** conceived, within AUGMENT project (1962,1968), the system NLS (oN Line System) at the Stanford Research Institute (SRI). During the elaboration of AUGMENT the team stored its articles, reports and memoirs in a shared electronic newspaper. Their investigations influenced in XEROX PARC and APPLE. Recently Engelbart devised the Bostrap Project of the University of Stanford.

Engelbart made two great contributions: the invention of the **mouse** and the **interactive computing,** and a kind of virtual reality. He presented a demo, with their own resources, in the Fall Joint Computer Conference 1968, causing a great impact.

3) **Ted Nelson** projected (1968,1990) XANADU at the RI of the Brown University (Providence,EEUU). Their project represents the beginning of HYPERTEXT. In 1990 the Xanadu Operating Company implemented several parts of Xanadu.

Perhaps the visionary idea of Bush is best expressed by the words of Engelbart:

"The symbols with which humans represent the concepts that they are manipulating can be placed before their eyes, stored, moved, called again, operated in accordance with very complex rules, -everything with a very quick answer -, by means of special instruments of cooperative technology "(1965).

Main Multimedia Issues**:** 1) Icon Environnement:WINDOWS (Engelbart, Xerox, Appl, Microsoft); 2) Link blazers (Bush); 3) Mouse (Engelbart); 4) Interactive Programming (Engelbart); 5) Virtual Reality (Engelbart, Lippman); 6) Hypertext (Bush, Engelbart, Nelson, Apple); 7) Multimedia/Hypermedia (Apple, others).

Thus, at the beginning of the seventies, the ideas of the 'multimedia group' found the willing technology for its realization (XEROX; APPLE). And, at the final eighties (1987), Hypertext reach HYPERCARD (APPLE), fruit of the initial investigations of XEROX (High Stick) and IRIS (Brown University). Steve Jobs built the Macintosh (1987) and later, toward 1990 (1988, first prototype), NEXT, the first experimental multimedia machine. Landmarks were Smalltalk, Apple Lisa and Apple Macintosh, and evidently Microsoft.

3.2. THE METAPHOR: SCENARIOS.

The metaphor is the main frame that reflects global vision of a multimedia interface and it links it to the environment of the user's tasks. It is an interface perceptive face and a scenario which user leaves in order to move, i.e., for where he will navigate. This also gives coherence for whole interface and Knowledge Base. Therefore, the metaphor supports the basic communication platform between user and system, i.e. a common house. The metaphor represents a main task in an interface conception. No it only plays the role of a menue, but rather it integrates the interface with the full application, especially the Knowledge Base.

The metaphor (an evironment of images) represents a plastic world in an icon language that perceptually integrates an application in an interface, as well as in the real world

4. Methodology.

MITS propose a method for: knowledge adquisition and representation,

a) knowledge flow diagram to navigate
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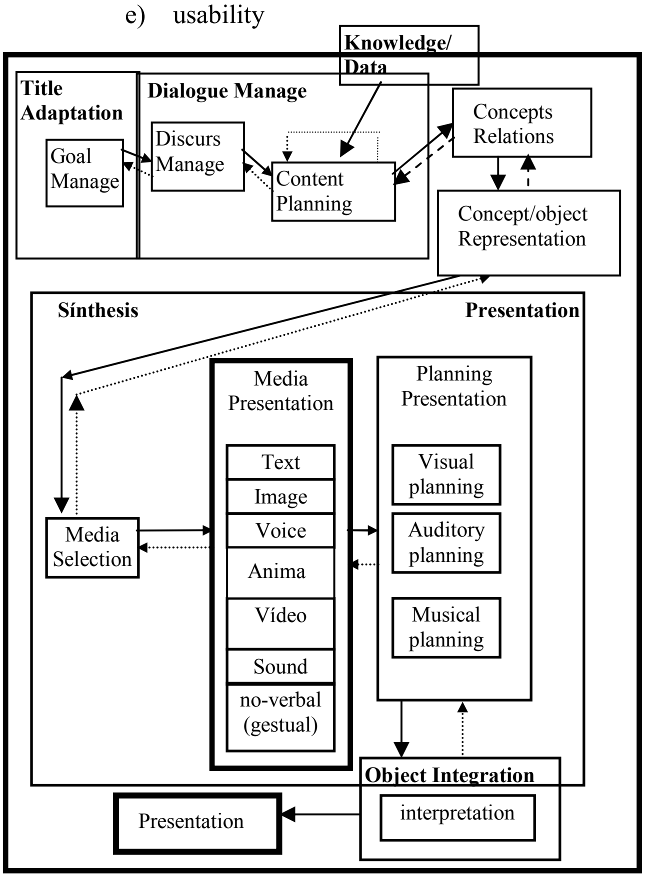


Sketch of the creation process of MITS

The previous outline illustrates the construction process of a multimedia application, highlighting the three basic stages that support the formative prototype: knowledge acquisition and organization, concept translation to media and media integration. Index and flow diagram facilitate, on one hand, the task of knowledge organization and communication with the domain expert, and on the other, the navigation through an entire application. [Lopuck,96].

4.1. KNOWLEDGE ADQUISITION AND REPRESENTATION.

The knowledge, the pedagogic strategy and the evaluation form are picked up from expert domain. This is carried out it by means of protocols and documents, and videofilms. The knowledge protocols establish a layout for the knowledge presentation of experts, looking for the possible more graphic and plastic form, for example, outlines, slides, transparencies, graphics, images, etc. The evaluation module represents a minimal subset of the Knowledge Base. Towards decomposition method in goals-subgoals (end-means) a path is settled down (top down) that should be continued between Knowledge Base and Evaluation Modules, the inverse one follows path bottom up. This path provides a strategy adapted to the student-user's profile by means of the student's pattern, preferences, individuality and errors. Genetic programming (algorithms) and fuzzy logic provides system control,and adaptation to the student, overcoming the difficulties of a causal model based on differential equations. Improvement also modulates explanations and personalised help adapting it to students. The Knowledge Base is established as a concept graph, for example, an extended semantic network: a acyclic directed graph interpreted by means of the multimedia objects. These objects are used as perceptive things. The classes worth/necessary for application are called the relevant conceptions. An instance is a relation between an image area and a relevant conception, often events, and its model is a concept with properties, that when they are perceptible we call attributes (real world features). So concepts have attributes and instances have attribute values. Thus we have relationships between classes, perceptive properties, and numerically testable (structural) relationships. The hierarchy forms a three-dimensional structure of parts, gen/specializations, and individualizations. A part is a relationship that decomposes a concept into subconcepts which represent conceptions of the same level of abstraction.There are primitive concepts and primitive actions.

An index can also establish expert/designer understanding of the domain.

The general structure of the requested information is similar to this, supposing that the chapter was the X-th and the section the Y-th:

X.Y.1. Approach
- X.Y.1.1. Summary
- X.Y.1.2. Lists of topic concepts
- X.Y.1.3. Index
- X.Y.1.4. Introduction
  - X.Y.1.4.1. Definition
  - X.Y.1.4.2. Justification
  - X.Y.1.4.3. Status quaestionis

X.Y.2. Position
- X.Y.2.1. Main explanation
- X.Y.2.2. Global approach
  - X.Y.2.2.1. Subapproach 1
  - X.Y.2.2.2. “ 2
  - ....
  - X.Y.2.2.m. Subapproach m

X.Y.3. Conclusions

X.Y.4. Examples
- X.Y.4.1. Hypothetical example
- X.Y.4.2. Real example

X.Y.5. Evaluation method

X.Y.6. Parallel relationships

We shall now explain certain points of the structure about proposed knowledge. X.Y.1. Approach: *this section tries to advance the insight that will be*. X.Y.1.1. Summary: *paragraph that summarizes the contents of the section.*

X.Y.1.2. Lists of topic concepts: *it defines the specific concepts of the done topic*. *To propose the definitions whose interpretation is basic for understanding the section, keeping in mind the user's formative level, selecting only the concepts that are supposed unknown.*

X.Y.1.3. Index: *an index that shows the structure of the development of the section.*

X.Y.1.4. Introduction*: introduction that will offer an initial, global vision of the section.*

X.Y.1.4.1. Definition: a *brief definition of the main concept of the section.*

X.Y.1.4.2. Justification: *to explain the importance of the section within the course and within the chapter.*

X.Y.1.4.3. Status quaestionis: the *current vision of the topic and the previous vision*

X.Y.2. Development*: the necessary theoretical explanations, supported by text/vision/sound.*

X.Y.2.1. Main explanation: *an introduction to the global approach developed in the next point*

X.Y.2.2. Global approach: this has the structure of the “Particular Index” seen before. It consists of m points that we denominate subapproachs and which correspond to the titles of each subpart where the content of the section is developed.

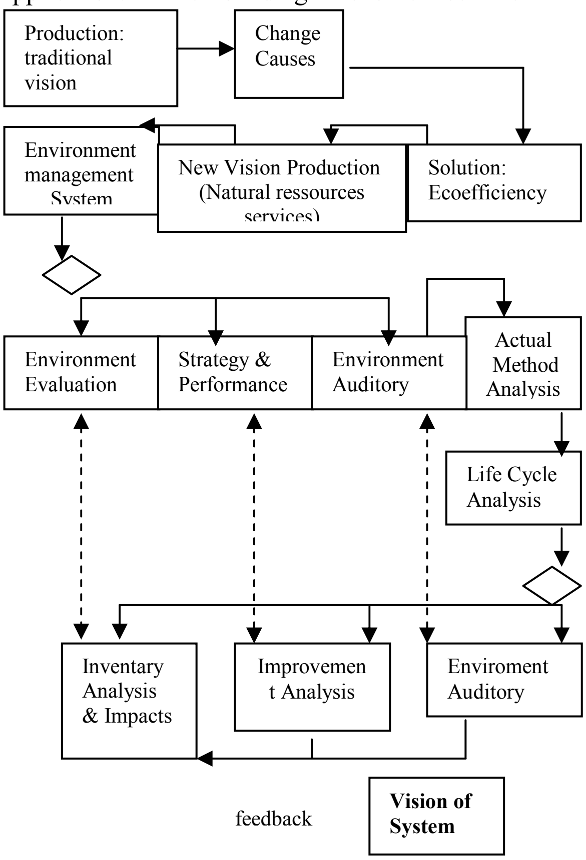
“Approach” provides a global vision with subparts. “Position” develops content of the section, and it follows the “Particular Index” proposed by the teacher. “Conclusions” tries to serve the student initially when not having a teacher to contrast own conclusions. All topic will have a series of examples. The teacher proposes a “Method of Evaluation”. “Parallel relationships” facilitates navigation for the whole application.

This index serves the designer as much as the expert and user, and this approach should reflect the general structure of domain presentation for the expert. What it cares about here is not the relationships among the concepts, that is to say, the flow of the knowledge, but the formal structure of the organization of the knowledge domain that the expert has. It is also useful to control that we are representing from the expert's complete approach, and that the interface shows at this site. In the case of several experts, this outline has to recover basically all its different visions. This is necessary because the expert has organized his knowledge in a complex way, which is difficult to predict, and he must be able to check that it is reflected from his vision, then for this reason, it should be edited in an intelligible way for him.

4.2. KNOWLEDGE FLOW DIAGRAM TO NAVIGATE

Once we have represented the fundamental concepts and their relationships in a concept graph, the following task is to design the concept flow diagram. This diagram follows the concept flow of the data domain, according to the expert's presentation.

This way we obtain the necessary information to determine the actual navigation for the application. Transition diagrams or statecharts can also be used An example for a possible flowchart for the domain of the "Environmental Management" :

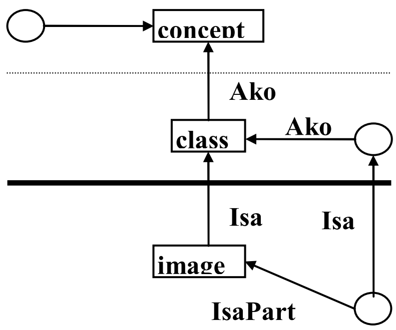


4.1. ORGANIZATION OF THE SEMANTIC NETWORK

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)



The perceptual subgraph contains (individual) objects, such as images. And their main relationships are "IsaPart" and "Isa" that formally represent set membership, and "Pros" (structural) relationships, such as spacial. This graph provides concept translation into media. The concepts/classes are represented by means of iconic images (prototypical) and text (names), and individual images and their parts. "IsaPart" inheritance is restricted by collective set axioms (Lesniesky) through levels of the hierarchical system. However "Ako/Isa" inheritance is supported by the transitivity of these relationships.

4.2. KNOWLEDGE TRANSLATION INTO MULTIMEDIA OBJECTS

RESMUL's semantic network provides a representation (interpretation) by means of

a) Static media: instances (individuals) of the extensional classes (text, graphics, images); do not have a time dimension, and their contents and meanings do not depend on the presentation time.

a1) Text: names of classes and concepts, and definitions, explanations, etc.

a2) Still - images

b) Dynamic (continuous, isochronous) media: having a time dimension, and their meanings

The representation continues analysing concepts in terms of iconic instances (prototypical) and individuals, as relevant knowledge (model). The aim is for the graphic representation to prevail

4.3. Multimedia object INTEGRATION

Media integration is carried out following the graph bottom up, so that we can travel the graph from the actual objects until the highest levels, that is to say the most abstract concepts.

Thus a image functions as a ***agent***, witch has a state, possesses an expertise, and is capable of initiating and reacting events, and when communicate directly with the user can be named ***interactor.*** An interactor provides users with perceptual representation of its internal state. ***Interaction objects*** are computational elements with a local state. This distributed agents may be **cognitive** or **reactive**. A cognitive agent is enriched with inference and decision making mechanisms to satisfy goals. A reactive agent has a limited computational capability to process stimuli. It has no goal but a competence script assigned.

Agent models stress a highly parallel modular organisation and distribute the state of the interaction among a collection of cooperating units. It is thus possible to modify its internal behaviour without endangering the rest of the system. And an agent can be associated to one thread of the user's activity. Since a state is locally maintained by the agent, the interaction between the user and the agent can be suspended and resumed at the user's will. It is possible to use a collection of cooperating agents. [Giunchigligia, 92] [Maybury, 93].

5. PRESENTATION, EVALUATION AND COMMUNICATIONS

This step follows the prototype constraints and interface properties, especially the usuability attributes observing task users in action [Hackos., 98]. Norman's seven-stage cycle establishes these seven steps: forming the goal and the intention, specifying and executing an action, perceiving and interpreting the state of the world, and evaluating the outcome.

multimedia objects, with the following functions for every object [Brugos, 93]:

and correctness depend on the rate at which they are presented. These media have their intrinsic unit interval or rate:

b1) Animations: processes and relationships among instances (individuals), and essential functions of classes and concepts

b2) Video: real images (photograms) of a).

b3) Voice: this is usually used to reinforce names and definitions, but mainly for the help *in situ*. [Lu, 96]

over the textual one, and to provide personalysed user interaction [Sagerer,97], [Adorni,84].

On the other hand, Distributed Multimedia (networks) requires a Quality Of Services (QOS) of five major elements: a QOS specifation mechanism, control to admitte application without affecting QOS of the other applications, QOS negotiation between application and system, resource allocation and schedulind, and traffic policing, i.e. traffic throughput, transmission delay, delay jitter, transmission reliability and synchronization. That is the temporal relationship which is peculiar to multimedia information, and (inter/intra media) *synchronization* is the problem for generation and replay, rather that in orchestrated (time-independent or discrete) but in live (time-dependent or continuous) applications. Multimedia over a network is *distributed*, at best on Asynchronous Transfer Mode (ATM) and BISDN (Broadband Integrated Service Digital Network) networks (SONET) rely on new integrated circuit switches, since fixed-sized cells are easier to handle than variable-sized cells. MPEG-4, scheduled for November 1998, experiments with wavelet compression, and MPEG-7, for November 2000, that will support interactive multimedia distribution in a multivendor client/server environment prepared by the Multimedia and Hypermedia information coding Expert Group (MHEG) [LU,96;Raghavan,98;Wu,98]

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