ON THE CONCEPT OF DATABASES OF MULTIMEDIA LEARNING MATERIAL (DBLM)

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This paper refers to the ESM_BASE (Educational Systems Based on Multimedia Database) project carried out within the EEC DELTA programme. The concepts of ULM (Unit of Learning Material) and of DBLM (Database of multimedia Learning Material) as resources for learning and as bases for courseware reusability in the authoring process are discussed in connection with possible developments of the educational market. A basic architecture for a DBLM is proposed which allows for different personalized views of the same DBLM to be used by different classes of educational applications. Educational processes based on learners' navigation in a DBLM guided by an intelligent tutor are also considered.

1. INTRODUCTION

The increasing use of technology in education and training together with the advances in the field of optical storage and communications are the main motivations for the implementation of the concept of databases of learning material as a resource for educational applications. A database supporting a variety of possibly distributed educational applications makes it possible to share the same material among many different users (learners and authors) and is a key factor in reducing the large amount of resources needed to develop high quality courseware.

A DBLM (DataBase of multimedia Learning Material) can be thought of as a resource which can be accessed and navigated by learners (in order to achieve specific informational or educational goals) and by authors (in order to design educational processes based on navigation in the database). While traditional courseware has a specific educational objective and is oriented toward a well-defined target population, a DBLM is only related to a specific content domain, but not necessarily to a specific educational objective or user [1]. This may depend either on the learner, who can select the units of learning material most suited to him, or on the author who can define classes of paths within the database which relate to specific educational objectives, or on the strategies of an Intelligent Tutoring System (ITS) which can dynamically guide the learner's navigation in the database. The same generality applies to educational strategies which should be defined outside the database by the author of a specific learning process. Finally, the learning resources within the database may be used in different technological contexts, to develop either non-interactive learning material or traditional interactive courseware or educational processes based on artificial intelligence techniques.

The hypothesis underlying this concept is that a new wider market is going to develop for educational software involving the distribution of content oriented rather than objective oriented learning material [2]. The use of a DBLM has interesting implications in the authoring and learning processes:

- it modifies the process of designing new learning material which does not have to start every time from scratch: already existing multimedia components can be selected by authors from a DBLM and imported into an application being developed within a specific authoring environment. This allows for actual courseware reusability in the educational design and may dramatically reduce the development costs of high-quality multimedia courseware.
- it provides more mature learners with a facility where they can autonomously build their own informative/educational paths [3].
- it provides the basis for a new type of educational system whose core is a database of learning material which fulfils the needs of different courses in the same content area.

2. A DBLM AS A RESOURCE FOR EDUCATIONAL APPLICATIONS

A DBLM can be regarded as:

- a stand alone resource to be accessed directly by the user for informative purposes.
This "open" use of the database requires suitable primitives and suitable user interfaces to help the user find the material which is most interesting and best suited to him in an easy, quick and natural way.

- a resource which can be accessed by any authoring or learning environment.

This implies the possibility for virtually any educational application to access a DBLM to retrieve potentially interesting material. For authoring applications this means finding and possibly modifying useful multimedia components in the database, and importing parts of them in the application being developed with a 'cut and paste' mechanism or with a run time query.

For learning applications this means the possibility for the learner to satisfy his needs or to develop his own personal interests by freely accessing the material in the database.

An interesting example is that of hypermedia navigation, which may be thought of, and implemented, as a specific client application of a DBLM.

- a pool of learning material where an ITS can select the most suitable units to present to the learner.

An ITS may help the learner find a path within the database to reach specific educational objectives. To assist the learner individually, a suitable model of the learner is required (and the related modelling system) as well as suitable representation of the content domain being taught. Given the amount of learning materials and the wide variety of alternative strategies available in a DBLM, the selection of the material most suited to the learner requires sophisticated decision rules based on adequate student modelling facilities.

3. ULM (UNIT OF LEARNING MATERIAL): THE BASIC INHABITANT OF A DBLM

This section aims at clarifying the concept of ULM, whose definition is a critical aspect deeply affecting the actual usability of a DBLM.

ULMs can be thought of as the basic blocks of learning material accessed by learners and by authors. The ULM is an abstraction which collects content segments of various media and types, hides their differences and offers a common and consistent interface in order to accomplish fruition and/or authoring activities [4]. All the multimedia aspects of the learning material are encapsulated in the definition of ULM.

ULMs can be simple monomedia objects, or the composition of other (simpler) ULMs. Simple ULMs may be of two types:
- Multimedia Sequence (MS)
- A MS corresponds to the delivery of a multimedia message to the user possibly including texts, still frames, dynamic sequences and digitized audio. No interaction is included in a MS except the standard one provided by the delivery system (quit a MS, altering the velocity of delivery, replay, etc.)
- Facilities A facility is any kind of (possibly interactive) program to be used by the author or by the learner to perform a specific educational function (a test, a simulation environment etc.)

The glue which binds together different ULMs in a composite learning sequence has to be provided by authors using a specific authoring environment. To ease the process of composition of ULMs in a learning sequence, each ULM is endowed with an Events Table which relates possible user actions (i.e. mouse clicking, keystrokes, timeouts, etc.) to activities to be performed by the system. When a ULM is opened only the "event side" of the table is initialized: the semantic actions are specified during the authoring phase.

4. A PROPOSAL FOR A CONCEPTUAL SCHEMA OF A DBLM

In this section an Entity Relationship (E-R) description model is used to describe the conceptual schema of a user view of a DBLM [5]. It should be noted that the choice of the E-R formalism does not entail a particular kind of data model and it is only considered a suitable language for communicating ideas [6].

4.1 A first step into the schema of a view

The two major entities in the conceptual model of a DBLM are the ULMs, the multimedia units of learning material, and the TOPICS, i.e. the specific elements of the content domain which a DBLM refers to. It should be noted that a set of topics does not involve a specific knowledge structure. On the other hand, many different structures can be imposed on the same set of topics.

ULMs are linked to TOPICS by the relation ASSOCIATED_TO. A ULM may be linked (refer) to one or more TOPICS, and a TOPIC may be associated to (many) different ULMs. The core of a DBLM can be characterized by the E-R diagram in fig.4.

The diagram also establishes that TOPICS have a single attribute topic_id, ULMs have mostly attributes of a rather objective and technical nature while the attributes of the relation ASSOCIATED_TO are of an educational nature and characterize the pedagogical function that a ULM may perform for a given TOPIC.
fig.1: a segment of the E-R diagram for the DBLM

4.1.1. ULMs' Attributes

A ULM is designed as an abstract object that hides all the implementation details and exports a set of features which are the only way to access the object. In this perspective a user can show or reuse a ULM without being concerned with all the technical details such as the different media involved, the physical location of the material (text and graphic files, video frame numbers), etc.: the fruition of any ULM is achieved through a small, simple and consistent set of primitives.

As an entity of the database, the ULM class exports values which are seen by the database user as the attributes of the entity. All the attributes of the entity ULM are values returned by methods of the object ULM.

These attributes can be grouped into three categories:

- **ULM identification**
  Each ULM is identified by a unique name, which is regarded as a primary key for the database.

- **content description**
  This category of attributes provides a mean to connote the ULM's content. Composed ULM are defined in terms of reference to the composing ULM and composition criteria (in space and time).

- **presentation attributes**
  The show method is redefined for each different medium subclass that a ULM may belong to: a user (human or program) can show any ULM with the same command, regardless the nature of the medium and structure of the material.

4.1.2. ASSOCIATED_TO attributes

ASSOCIATED_TO is a fundamental relation in the database which establishes a link between topics and ULMs making it possible to retrieve the set of ULMs referring to a given topic or the set of topics involved in a ULM. This many to many relation has the following attributes:

- **educational function**
  Each association ULM-TOPIC is characterized by the specific educational function which the ULM performs in connection with that TOPIC. Possible values for this attribute are {exposition, explanation, description, assessment, drill&practice, simulation, ...}.

  It should be noted that if we admit that the same ULM may exhibit different educational functions for the same TOPIC, it could be more appropriate to represent the educational function as an entity rather than as an attribute. In this case the relation ASSOCIATED_TO would became a ternary relation between ULMs, TOPICS and EDUCATIONAL FUNCTIONs.

- **completeness**
  The association between a ULM u and a topic t is characterized by an educational function e. If the ULM u performs e in such a way that nothing more is needed to accomplish e for the topic t we say that the triple \((u, t, e)\) is complete. If u performs only part of e for the topic t, then we need more ULMs to accomplish e for t and, in this case, we say that \((u, t, e)\) is not complete.

  If \((u, t, e)\) is not complete, then u is of little use to an automatic tutor willing to perform e for the topic t since no information is contained in the database about how to combine u with other ULMs to fully accomplish e.

- **knowledge type**
  This attribute specifies the nature of the knowledge that a ULM can transfer to a learner in connection with a given TOPIC. Possible values are {theory, data, facts, hypothesis, deduction, instance, concept, rule, skill, ...}

- **learning objective type**
  Traditional classifications of learning objectives usually refer to the affective, psycho-motorial and cognitive domains. For each domain specific taxonomies have been developed. In our case, to specify a set of values for this attribute, it is more interesting and appropriate to refer to taxonomies of cognitive objectives. Referring to Bloom's Taxonomy the set of values for this attribute could be {knowledge, comprehension, application, analysis, synthesis, evaluation}

- **approach type**
  This attribute specifies the way in which a ULM approaches a given TOPIC. It should be noted that the set of possible values for this attribute are often domain dependent (as an example think of ULMs referring to alternative theories to explain the same phenomenon). A generic set of values for approach type could be {inductive, deductive, concrete, abstract, formal, intuitive, traditional, historical, ...}
4.2. Including content representations in the DBLM

4.2.1. Reasons for including knowledge representation in a DBLM

At an earlier stage of this project, keeping the knowledge structure information outside the database was considered a cleaner solution. In this view, a knowledge representation should be considered as a set of links (external to the database) connecting a set of TOPICS (internal to the database).

Eventually it was decided to include structures in the database for two independent reasons: first, the association between ULMs and TOPICS is not an absolute one, but it is relative to a specific knowledge structure, and second, it may be difficult to keep the knowledge structure (outside the database) consistent with the set of topics (inside the database).

4.2.2. How to represent knowledge structures in a DBLM

Each structure can be represented in the DBLM as a set of typed links between topics. To this purpose a relation LINKED_TO between TOPICS and TOPICS has been introduced in the conceptual model of the database (see fig. 2).

The attribute link type allows for a variety of different knowledge representation techniques (hierarchies, Petri Net, semantic networks, ...).

It should be noted that the relation LINKED_TO is ternary since it involves also the entity STRUCTURE which specifies the knowledge structure in which two TOPICS must be considered linked. The type of knowledge structure (hierarchy, Petri net, semantic network, ...) is specified by an attribute of the entity STRUCTURE.

The E-R diagram in fig. 3 shows the complete skeleton for the conceptual model of a view in a DBLM.

5. PERSONALIZATION: A DBLM AS A HIERARCHY OF VIEWS

5.1 Hierarchical structure of a DBLM

The idea of a DBLM supporting different users and, therefore, different learning and teaching needs and objectives within the same content area entails a flexible structure allowing for different views of the database. For example, an author might wish to enhance the data base (with new ULMs, new links between database entities, new STRUCTURES, etc.) or to modify the qualification of the material inside the database to make it more suitable to the nature of the application being developed. Besides, among the users of a given view, some might wish to go further in the personalization process, while maintaining that view as a starting point.

This leads to the organization of a DBLM as a hierarchy of databases (views), each belonging to a user or group of users, with a responsible person regarded as the author of the view.

Theoretically, there is no limit to the depth or width of the hierarchy. The conceptual scheme of each view is inherited from the root and, for practical reasons, it is assumed that it cannot be altered by the view authors. However, in order to cope with the needs of specific educational applications, view authors may modify the range of possible values for entity and relation attributes. Several problems may arise from this structure such as the integrity and the internal
consistence of a view with respect to modifications taking place in other views and the unnecessary duplication of learning material stored in more than one view. These problems require suitable criteria and rules for an efficient management of the collection of views. Such criteria may be referred to as the dynamic aspects of the personalization process, as opposed to the static ones, i.e. the hierarchical structure of the DBLM.

Among the possible solutions of view management problems, we envisage here a combination of a pure inheritance mechanism and a simpler copy and paste approach, which minimises the drawbacks of both.

In this approach a view may inherit part (or all) of its ancestors' content. This means that any modification to the parent view also affects its sons (pure inheritance). In order to prevent unexpected inconveniences resulting from lack of concertation among the authors of different views, this default mechanism may occasionally be overridden by copying and pasting those parts of the database which are shared by a view and its ancestors.

6. NAVIGATION IN A DBLM GUIDED BY AN INTELLIGENT TUTORING SYSTEM.

This section aims at providing a possible model of operation for an Intelligent Tutoring System guiding the navigation of a learner in a DBLM [7][8].

A tutorial program should first build an initial model of the learner including her specific learning objectives [9]. On the bases of such model it should be able to chose the knowledge structure to be used (if more than one structure is available).

After the initialization phase, the questions that an ITS has to answer again and again during its interaction with a learner are: "what to teach next? how to teach it?". The steps that a DBLM based ITS should go through to answer these questions are summarized below.

a) select a set of topics compatible with the educational objectives and with the status of the learner.
   The first step consists in deciding which topics may be taught to a specific learner at a given time. Criteria for making this choice will take into account the model of the learner (especially the domain dependent aspects of the model) and a specific knowledge structure in the current user view.

b) select from the set the 'best' topic to be taught first
   Here the word best has no absolute value:
   it refers to criteria established by the ITS designer. It should be noted that these criteria do not belong to the DBLM. On the contrary, they can be defined in many different ways for different client applications of a DBLM. Possible criteria are: "Teach first the topic having more connections (in the knowledge structure being used) with topics that the learner already masters" or "Teach first the topic having fewer connections (in the knowledge structure being used) with topics unknown to the learner"

Of course applying these criteria requires the knowledge of the current status of the model of the learner.

![Fig. 4: Mode of operation of a DBLM based ITS](image)
To implement a given strategy (composed of educational function \( e_1, e_2, \ldots, e_n \)) for a given topic \( t \) an educational system should look for the ULMs performing \( e_1, e_2, \ldots \) for that topic (educational function is one of the attributes of the ASSOCIATED_TO relation in the database). Also the type of learning objective to be achieved in connection with \( t \) and the type of knowledge to be transferred to the learner should be taken into account (knowledge type and learning objective type are also attributes of the ASSOCIATED_TO).

Select the best ULM to perform a given educational function. If more than one ULM is available in the database to perform a given educational function for a given topic the choice could privilege the best approach type for that learner (approach type is an attribute of relation ASSOCIATED_TO in the database).

The detailed structure of the student model used in the ITS is at present under development. More specifically, it includes a content dependent component (mostly assessable via diagnostic evaluation of the student knowledge) and a content independent one, including such things as affective components and learning style. Information about the latter may partly be directly elicited from the student and partly inferred through a systematic analysis of the history of his interaction with the system.

7. CONCLUSIONS AND FUTURE DIRECTIONS.

We have proposed a conceptual model for a DBLM. This model should be considered as a first step in the exploration of the concept of DBLM as a mean of saving, communicating and sharing knowledge.

This model is now being implemented through the development of a shell and of a specific DBLM in the field of Plate Tectonics.

These prototypes will be used to validate the conceptual model in three different directions:

- experimentation with instructional processes based on learner directed navigation in the DBLM on Plate Tectonics [10]
- implementation of an ITS for guiding user navigation in the DBLM
- experimentation with an author environment linked to the DBLM.

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8. REFERENCES