An Adaptive Learning System Architecture based on a Granular Learning Object Framework

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ABSTRACT
Adaptation has been becoming more and more important in modern educational systems. Building an adaptive learning system requires granular and reusable content. In this paper, we proposed a learning content framework using the Learning Object technology. We will particularly examine the granularity approach of Learning Objects (LO) and its impact of adaptability in Adaptive Learning Systems (ALS). For this, we study first the concept of Learning Objects. Then, we present some models of educational contents and their limitations in comparative way. Afterward, we discuss the granularity as a fundamental point to achieve adaptability and individualization required in Adaptive Learning System. Later, we propose our own learning resources model that emphasizes on fine-levels granularity to enable course adaptability and therefore facilitate efficient learning to the students. Finally, we present the design and the general architecture of the system ALS-CPL, allowing the integration of the granular LO framework.

Keywords
Adaptability, Learning Content, Adaptive Learning Systems, learning object, granularity, learning content model, individualization

1. INTRODUCTION
Various researches in the field of Adaptive Learning Systems (ALS) were interested in the content models based on the Learning Objects approach. Most of them, especially the standard LOM [1], SCORM [2] or CISCO, developed content models generally based on different aggregation levels of learning content.

These models have tried to decompose the content into a set of items or block elements having a pedagogical sense, also called Learning Objects (LO) or learning grains. Defined items, although they can be reused in educational platforms, probably does not fully satisfy the concept of "fine grained" we seek to identify in aligning ourselves with the work of several authors such as [3, 4, 5, 6, 7, 8]

Those works propose conditions that are generally related to size, integration context and the idea associated with the Learning Object.

The model that we propose in this article is between these different approaches. Indeed, it offers fine enough granularity to reach the reusability and adaptability of a curricula.

We are interested in this paper to the learning content granularity and its impact on the ability to adapt, aggregate and to arrange content suiting the needs and preferences of the learner.

The aim of the remainder of this paper is structured as follows. We will firstly begin by "demystifying" the concept of Learning Objects and its granularity. We explore next, some structural issue of content models. The section four will appreciate the granularity, as a fundamental characteristic to achieve adaptability and individualization in the field of ALS. In the next section, we propose our own content model and study next its ability to meet the supposed objectives of adaptability. Finally, we present the architecture of our system called ALS-CPL (Adaptive Learning System - the C Programming Language) that is currently being finalized then we discuss the ability of this work to achieve the adaptability required in ALS in a correlation of other works [16]-[17].

2. THE LEARNING OBJECT APPROACH
The "Learning Object" (LO) is a new name that emerges in the field of educational resources and learning, which does not escape to ambiguity. Most proposed definitions focus on the general principles governing concept of LO such as: reusability in different situation for learning and the independence of context [9].

Balatsoukas [8] gives a typical example of the Polsani definition [7]. This author defines a LO as a unit of content Learning independent and autonomous, which is predisposed to be reuse in multiple learning contexts. Other authors such as Bibeau [10] considers LO as the smallest information unit or the smallest processing tool information (or applications software) used in an educational context with an intention teaching for learning through the media technology. Flamand & Gervais [11] identify three categories of learning objects. They distinguish objects with little media complex and context-free (video speech of a head of state radio interview, etc.) utilitarian (modeling software, etc.) and LOs consisting of elements basic information (facts, ideas, concepts, principles, processes).

Finally, other approaches such as those of Downes [6] consider the size of a LO as important. Barron [4] trying to consider this approach, suggests that five to nine information objects (text, image, video, photos, etc.) can be combined to form a LO. Other works of Mortimer [5] undertaken in this direction, and including approach the size of a LO in terms of time. A LO takes no longer than 15 minutes to complete.

In addition to these theoretical conceptualizations and sometimes ambiguous, other definitions emerge from various works on standardization (SCORM, LOM, IMS, etc.). For IEEE Learning Technology Standards Committee, Learning Objects are defined here as any entity, digital or non-digital, which can be used, re-used or referenced during technology supported learning. Normetic [12] adds to this definition, the technological support that covers the multimedia content, content instruction, educational software and software tools mentioned in a learning context to support technology. Finally, the center of Wisconsin online resources [13] defines a LO as "small learning units with a duration between 2 and 15 minutes".

In the following, we propose an exploration of the issue of educational content. For this we will study some content models in relation with the new works on the concept of "learning objects" and the work on standardization and related technologies.

3. OVERVIEW OF SOME OF LEARNING OBJECT CONTENT MODELS

The Content Model describes the components used to build a learning experience from Learning Object. The content model also defines how these lower level learning resources are aggregated and organized into higher-level units of instruction. There is much of Learning Object Content Models in the literature. In this section, we study briefly some of the content models for e-learning: SCORM content model, the aggregation level defined by IEEE LTSC and the Cisco systems Reusable learning object content model. Finally we will present a summary of those models in a comparative way.

3.1 The SCORM content model

The Sharable Content Object Reference Model (SCORM) integrates a set of related technical standards, specifications, and guidelines designed to meet SCORM's high-level requirements: accessible, interoperable, durable, and reusable content and systems adlnet [2]. SCORM has three main components: the content aggregation model, runtime environment and navigation and sequencing. We are interested in this section in studying the first component: the content aggregation model

The content aggregation model defines a structure with three levels aggregation: assets, Sharable Content Object (SCO) and Content Organization (CO). An asset is the basic building block of a learning resource. The assets may be text, animations, images, videos, etc. A SCO is a compilation of one or more assets. A SCO represent the lowest level of granularity of a single learning resource that communicates with an LMS using SCORM Run Time Environment. A CO is a representation that defines the intentional use of the content through structured units of instruction. The representation shows how activities relate to one another.

We note that SCORM does not recommend the size of a SCO or that of a package. We also note that the assets and SCOs may be reusable, unlike COs who may not be reusable given that they depend on a set of rules of sequencing and navigation of a defined course or a lesson, etc.

3.2 The IEEE LTSC content model

The IEEE Learning Technology Standards Committee identifies four different levels of learning object aggregation or "functional granularity" of learning objects Ballantyne [14]. These levels of aggregation are implemented in IEEE Learning Object Metadata (LOM) standard. The IEEE LOM is a data model used to describe a learning object and similar digital resources used to support learning. The purpose of learning object metadata is to support the reusability of Learning Objects, to aid discoverability, and to facilitate their interoperability, usually in the context of online learning management systems.

The four levels of aggregation defined by IEEE LOM are:

1) Level 1: The smallest level of aggregation, e.g. raw media data or fragments.

2) Level 2: A collection of level 1 learning objects, e.g. a lesson.

3) Level 3: A collection of level 2 learning objects, e.g. a course.

4) Level 4: The largest level of granularity, e.g. a set of courses that lead to a certificate.

3.3 The Cisco systems RLO content model

Cisco Systems published a strategy based on the concept of 'RLO / RIO'. A RIOs (Reusable Information Object) is a reusable granule of information that is built around a single learning objective. A RIO is presented under five forms: a concept, fact, procedure, process or principle, and associated with assessments (usually two) to evaluate the learner's assimilation of different concepts, facts, etc.

A RLO (Reusable Learning Object) is the result of a combination of five to nine (7±2) RIOs. To construct a complete learning experience or lesson from a set of RIOs, an overview, a summary and an assessment are added to the packet.

Moreover, this model defines other level of granularity: a course is composition of module. A module is a collection of RLOs. An RLO is a lesson. A RIO is a topic composed of sub-topics (definition, example, tables, etc.). Finally, we note that the Cisco model considers each level of aggregation as a learning object.

3.4 Summary

To summarize the previous section, we have grouped the various models presented above in a summary table (See table 1). This table is used to highlight the relationship between the concept of granularity and that of reusability.

We find that the more granular content (asset, multimedia, etc.), the more the possibility of reuse of this content increases. In addition, the more the level of aggregation increases (CO, courses, etc.) the more the content is depending on the context and the less it can be reused out of this context [9].

Table 1. Summary of some of content models (inspired by the work of [8]

SCORM	IEEE LTSC LOM	CISCO RIO/RLO
Asset	Level 1	
SCO	Level 2	RIO /RLO
COs	Level 3 Level 4	Module courses

Fine granularity

reusability

The various models are based on a definition of granularity focused on the media. The LO granularity is directly related to the media which is the smallest that will be combined to create larger LOs. It uses the concept of level of aggregation instead of granularity and provides models of educational content that provide a means for defining the structure.

In all these models, the first level (Asset, RIO multimedia object) cannot really match the criteria of sense unless the grain is associated with an educational objective. The size criterion is not necessarily considered and generally depends on the designer. Indeed, in most of these models there is no information about the size or the semantic density (number of idea) of o LO. In addition, the standard definition of a LO differs from one model to another. Each model is a specific profile. LO defines a model can't be reused in another model.

4. GRANULARITY VS ADAPTABILITY

In the field of ALS, adaptability refers to the capacity of the systems to automatically adapt the content at every moment to the needs, goals and preferences of a given learner. In this section, we are interested in a specific dimension of adaptability which is usually omitted in the literature. This dimension deals with the influence of fine-grained content on the adaptability and individualization required by the dynamic adaptive hypermedia for learning.

The granularity is a process that involves breaking down educational content in a set of items or blocks having a pedagogical sense, also called grain. These grains can be combined and re-assembled to create coherent curricula. So, the LO granularity is a key factor to enable aggregating and organizing content and create curricula that are adapted to the preferences, goals and needs of a given learner.

How to separate the content differs from one model to another. The most used technique is the aggregation. The concept of "granularity" is almost absent; except for some work such [3, 4, 5, 6, 7, and 8].

These authors were interested in the conditions needed to determine the type and level of granularity to consider. For Wiley [3], the granularity of a LO depends heavily on the context in which the grain will be inserted. Other authors such as Polsani [7], argue that the granularity depends on the size of a LO. The size specified by the author corresponds to the number of ideas that a LO can transmit.

The "fine-grained" in our point of view, is to combine the concept of meaning, idea and size as a unifying principle, which frees the LO of any considerations related exclusively to the size as the time or the subjectivity of the designer.

Insufficient granularity (eg using large blocks of content), probably prevents the possibility of integrating the content in new contexts and new ALS.

However, breaking down content in several LOs having a meaning and carrying a main idea, allows several options for adaptation. The first option is to consolidate and arrange multiple LO to create other objects more robust and reusable. The second possibility is to build and customize a LO by offering several presentations with different computer interfaces. Another possibility involves a classification of LOs in the classes of objects (eg theorems, definitions, etc.), which allows the filter more easily, improve research and thus to individualize the content.

5. A MODEL OF EDUCATIONAL RESOURCES

In this section we propose a model for learning objects. This model is flexible, respects the standards and it is able to build content dynamically from basic fragments based on the representation of the learning domain and the learner model.

The proposed model is not specific to a particular learning domain, although it is designed for learning programming languages for novice learners. It features a structure in terms of grain content (Fragments Brick multimedia, etc.), and the concepts of domain covered.

5.1 A model of Learning Object

To enable a good structuring (granular) content, applying the principles outlined above, we have broken our educational model in two complementary levels: the structural level and semantic level.

For the structural level (See Figure 1), it corresponds to the structural organization of content. In this level, the central concept is Document. A document can be a course's document or an additional document. A course's document can be generated from a set of fragments composed of different learning resources (introduction, definition, example, exercise, paragraph, comment, evaluation, synthesis, or illustration).

Each of these fragments is described by bricks multimedia: text, image, sound, video, simulation, animation, etc. We note that each fragment can achieve an educational goal related to a concept of curricula.

Regarding the semantic level, it consists of different meta-data for describing the different fragments. Here, we used some elements of the Education section of the LOM standard. A fragment is described by descriptors such as: type (exercise, example, definition, etc.), the type of interactivity (active, collaborative, communicative, and undefined), the level of difficulty (easy, medium, and difficult), the estimated time, the list of bricks multimedia, and context of use (in one or a combination of concepts).

Finally, other attributes as part of the general description of a fragment have been introduced such as ID, title, author, language, keywords, and pre-requisites. In addition, each block is described by media other descriptors such as: size, format, identifier of the fragment, and physical location.

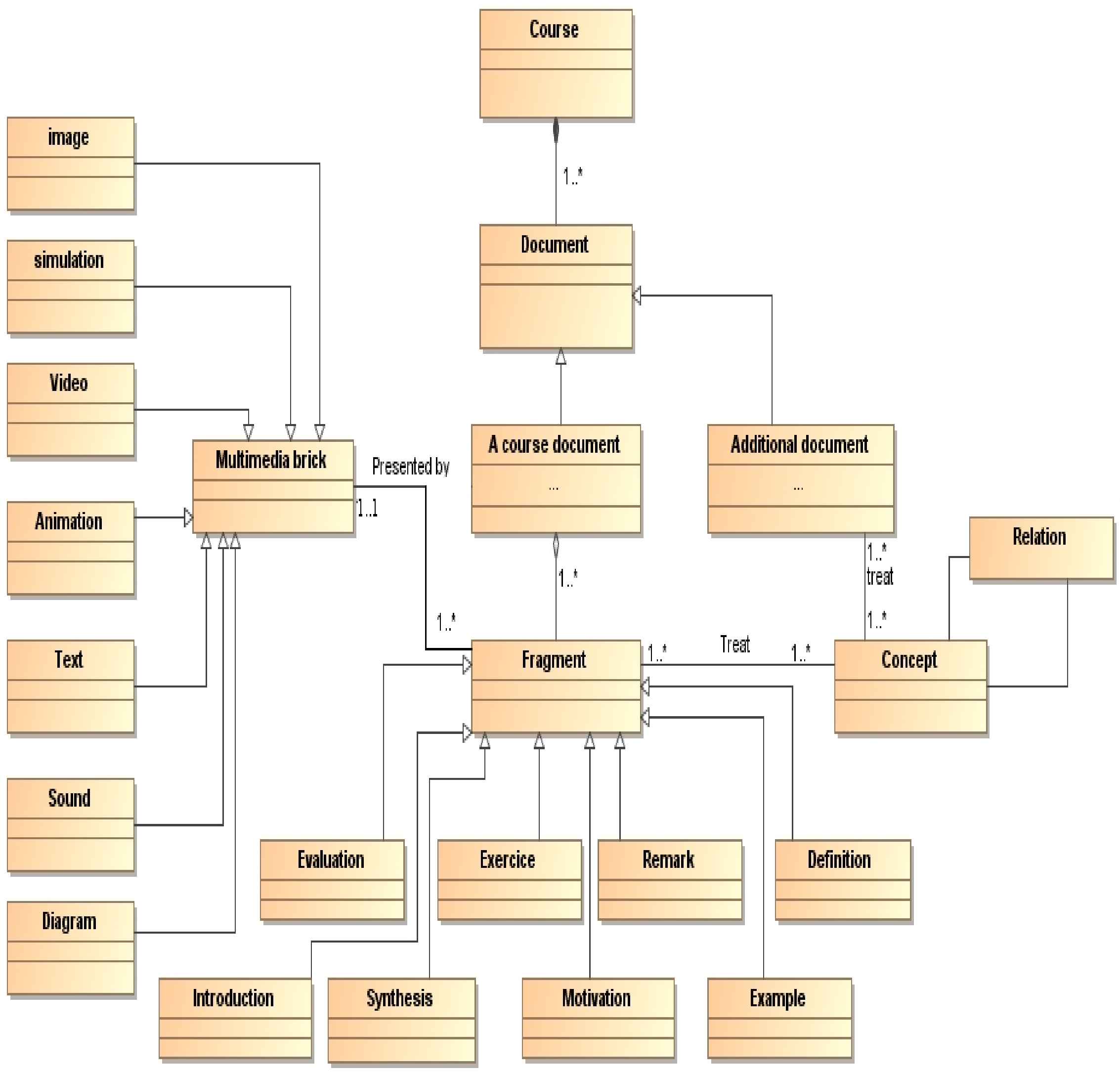

Fig 1: Structural pattern of digital learning resources [9]

5.2 The domain model

The domain model we propose is represented by a graph of concepts and relationships between these concepts (Figure 2, Figure 3).

We recall that the concepts are the knowledge to be acquired by the learner. Each concept is connected with fragments themselves pointing bricks multimedia. This model can be instantiated according to the learning model described (Figure 3)

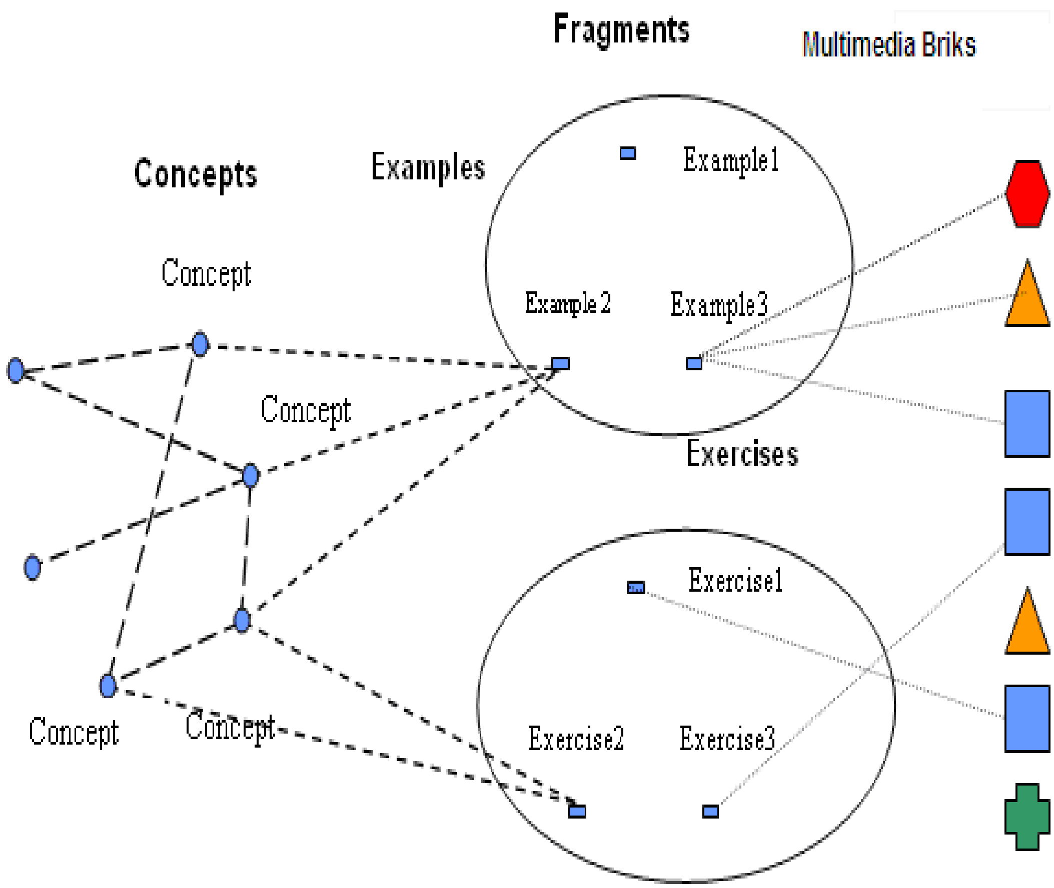

Fig 2: Representation of the learning domain (inspired by work of Brusilovsy [15])

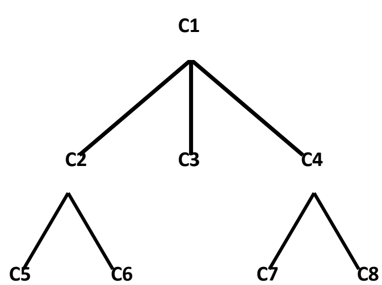

Fig 3: The Learning concepts graph.

Relationships (or links) between concepts can be different types. The links "pre-requisites" for example, indicates that learning a concept C1 requires the mastery of the concept C2 which precedes it. The links "Composition" means that the description of the parent node is performed using the description of its components. The links "generalization" expresses that a node represents a generic concept and its successors describe the subclasses of this concept, i.e. more specific concepts.

6. TOWARDS AN ALS ARCHITECTURE

In this section we illustrate some functionalities of our system called Adaptive System for Learning the C Programming Language (ALS-CPL) which is under development and finishing.

Actually, the architecture ALS-CPL implements the LOs infrastructure, the domain concept structure and the learner model interface.

The architectural design of the proposed system is composed by three main components. In this section we present these components, their descriptions, their features and interactions between them (See Figure 4).

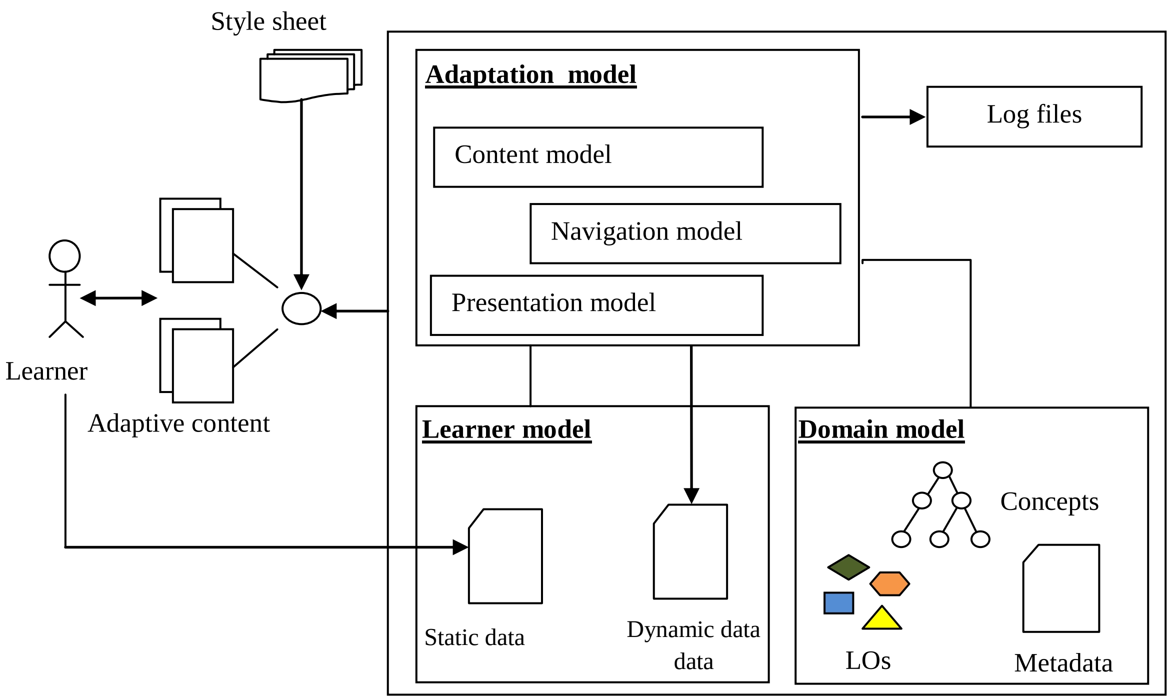

Fig 4: General architecture of ALS-CPL

From this figure we identify directly the main components of an ALS and their contents in terms of subcomponents.

6.1 The Domain model

The domain model is characterized by its competence in terms of representation of concepts to teach, the resources available to learners and the structuring of various elements of the field

We have separated the domain model into two parts: one that includes all domain concepts that the learner can learn, regardless of the different kind resources that enable the acquisition. The second part, the most important for our work, concerns the learning resources used for the acquisition of these concepts accompanied by their metadata.

This part as we said, consists of an editor (See Figure 5) of LOs and reflects the semantic model presented above. This component uses PHP code to load an existing LO to be edited. It also allows the creation of a no existing LO. To assure the reuse of the LOs, it is necessary to qualify them by exploiting meta-data and the necessary descriptors so important to characterize each LO. We have used descriptors coming from standard LOM.

The multimedia bricks and concepts (Learning goal) can be associated to the LO. Other items for indexing LOs are added in this step. As output, an XML file is generated (e.g. Figure 6).

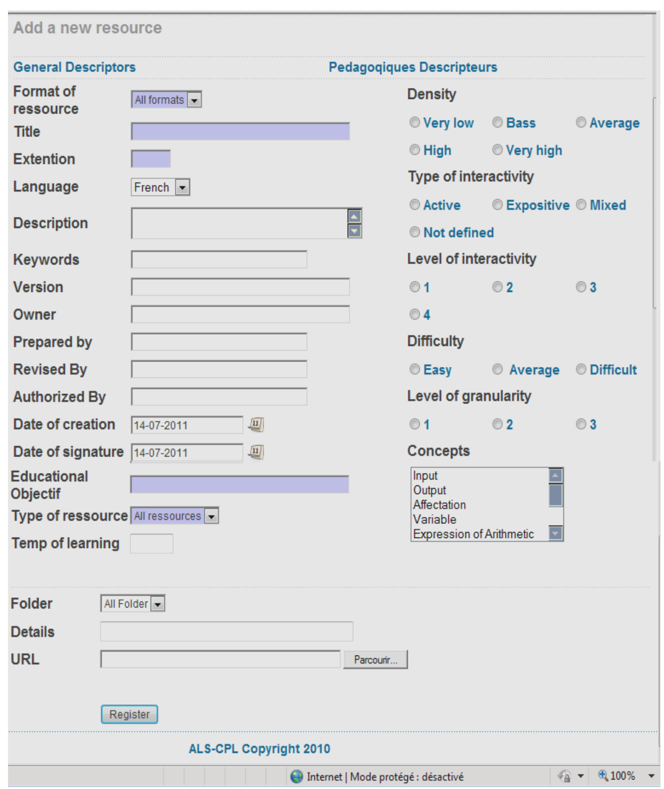

Fig 5: Creating / Editing a learning Object.

```
<?xml version="1.0" encoding="ISO-8859-1"?>
<metadata>
<general>
        <identifiant>introduction_scanf</identifiant>
        <intitule>introduction au concept
        scanf</intitule>
        <langue>fr</langue>
        <description>cette ressources introduit les
        concept de la fonction d'entrée
        scanf()</description>
        <keyword> scanf, fonction d'entrée,
        introduction, concept</keyword>
</general>
<lifecycle>
        <version>1</version>
        <statut>final</statut>
        <author>Masha Nikolski</author>
        <mail></mail>
        <organisation>CS Department,
        Technion</organisation>
        <date> April, 2006</date>
…..
</metadata>
```

Fig 6: Example of an XML file of metadata

6.2 The learner model

The learner model represents the information (See Figure 7, Figure 8 and Figure 9) known by the system about the learner. Three strands of information are considered: personal (name, email address, phone, etc...), preferences (language preferences, favorite colors, the preferred type of educational content, etc...) and Knowledge. Knowledge of learner is described in relation to each domain model. This component evolves dynamically as the student progress in his course.

For this component, we make it open for editing and viewing by both the learners themselves and the system. This with the aim to involve the learner in the construction of his model so that it contains information and make it more reliable and more representative of the learner. For our model, it consists of two main parts:

- Static data: the data is indicated by the student during his first access to the system and can be updated by the learner at any time of his learning.
- Dynamic Data: This data is updated only by the system and highly dependent on the results and interactions of the learner with the content presented.

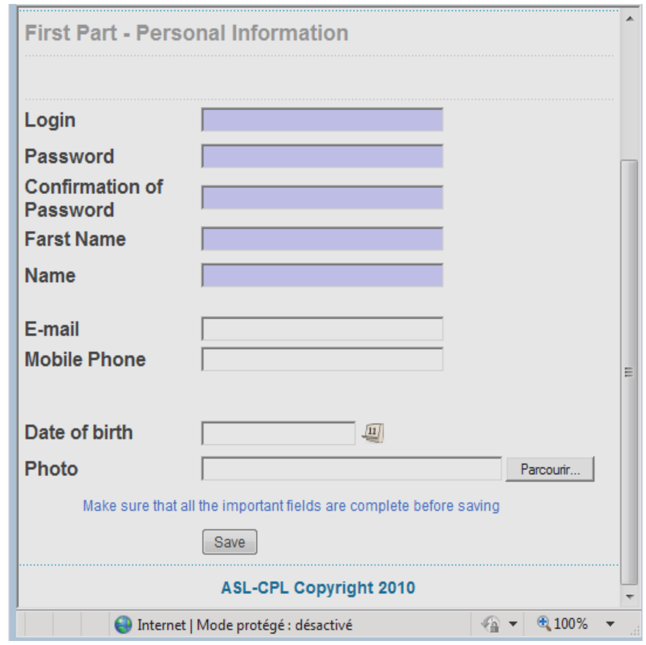

Fig 7: Editing personal information in ALS-CPL.

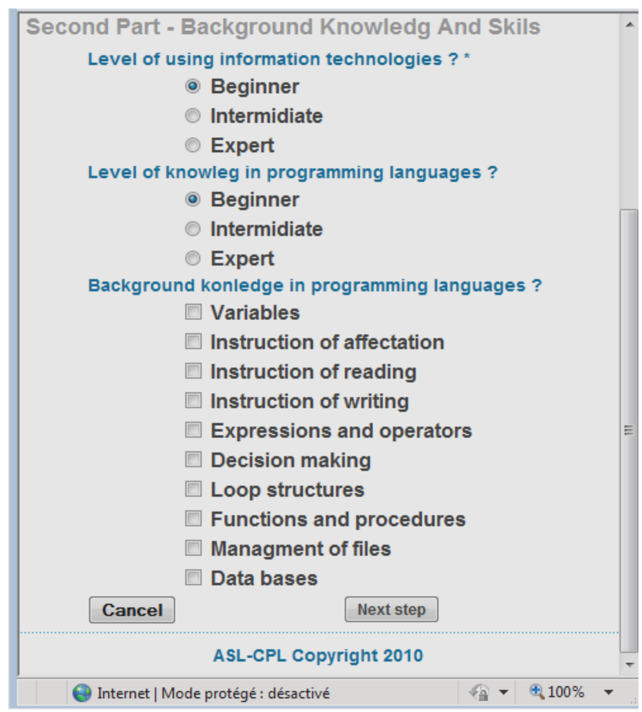

Fig 8: Editing background knowledge and skills of a learner.

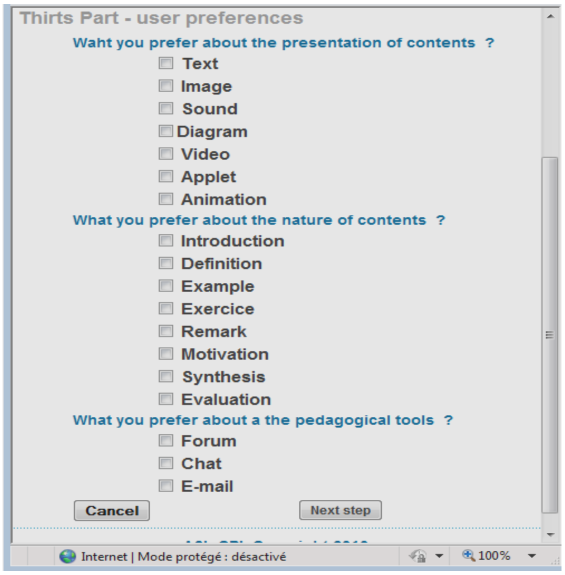

Fig 9: Editing preferences of a learner.

As output, an XML file is generated. Figure 10 presents an example of a model learner.

```
<?xml version="1.0" encoding="ISO-8859-1"?>
<?xml-stylesheet type='text/xsl' href='transf.xsl'?>
<!DOCTYPE apprenant SYSTEM "apprenant.dtd">
<apprenant>
    <statique>
        <identification>
            <nom>battou</nom>
            <prenom>amal</prenom>
            <sexe>f</sexe>
            <date_de_naissance>27/09/1979
</date_de_naissance>
            <telephone>0661159341</telephone>

<email>amal.battou@gmail.com</email>
        </identification>
        <securité

<password>16b5480e7b6e68607fe48815d16b5d6d
</password>
                ….
    </statique>
    <dynamique>
        <concept> </concept>
        <note></note>
        <etat_emotionnel></etat_emotionnel>
            …
    </dynamique>
</apprenant>
```

Fig 10: Example of an XML file of a learner model

6.3 The adaptation model

The adaptation model deals with the generation of adaptive content that will be subsequently presented to the learner. This component has three sub-components: the navigation model, the presentation model and the content model. Each sub-component contains a set of rules to achieve the adaptation

1) *The model navigation*: The navigation model defines the structure of the hypermedia system and describes how to traverse the various nodes of the system.

2) *The presentation model*: it is used to adapt the layout for the visual line with the preferences or needs of the learner.

3) *The content model*: this model is used to provide additional content, similar content, alternative content, or hide content.

The process of how these sub-components is as follows (Figure 11)

In the simplest case, when a learner interacts for the first time with the system, the list of the acquired concepts is empty. The concepts that have no pre-requisites in the graph of the concepts and have not been acquired will initialize the list of the active concepts, which enable to choose the objective of the session.

Some elements of the learner model can influence this decision. These considerations come from the background knowledge and skills of the learner represented in the learner model like the level concerning the programming languages (beginner, intermediate, Expert), or the background knowledge composed of a set of programming concepts (variables, decision-making code, loop structures, procedures and functions, data bases, etc.). Some pedagogical rules for such a decision are applied.

The choice of one or more concept(s) associated with other information coming in particular from representations of the learner, determines a sequence that will then be derived in fragments (Fig. 11). If, for example, the model of the learner indicates that he (she) prefers to learn by examples, the sequence will consist of more examples. For exercises, the difficulty level will depend on information extracted from the model of the learner corresponding to his level (Beginner, Intermediate, and Advanced).

This sequence corresponds to a prototypical sequence of fragments to achieve the selected learning concept. For each fragment of this sequence, the system associates a multimedia brick, still according to the model of the learner. If the learner model indicates for example that learner prefer pictures and videos, the system will promote anything that is multimedia. If he (she) prefers reading on the screen, the text associated with fragments will be used to create a course document.

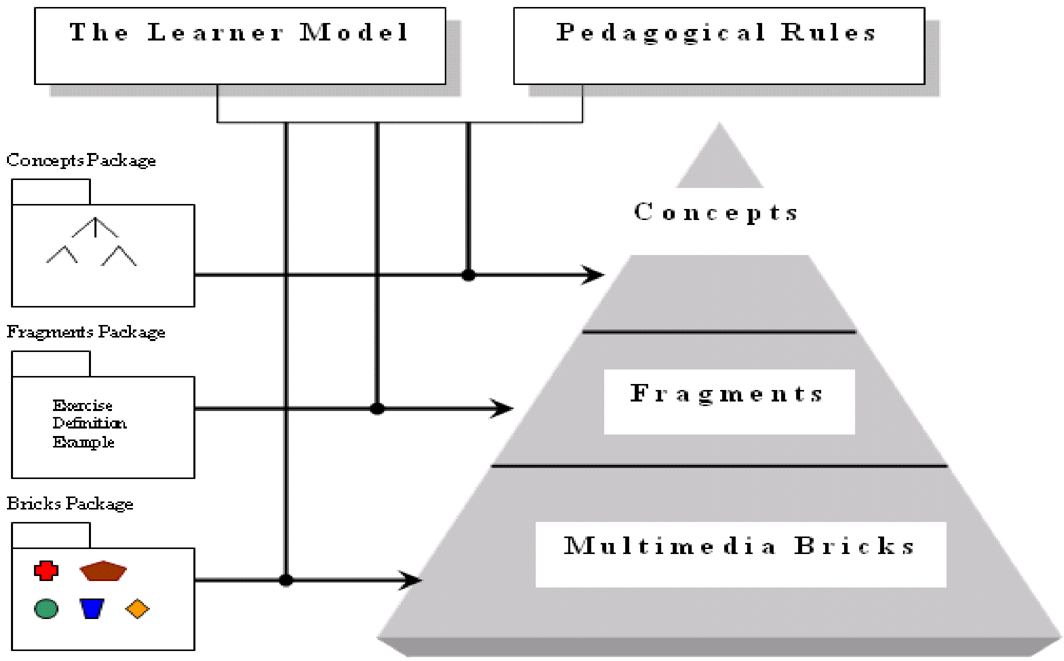

Fig 11: The assembling courses process [9].

7. CONCLUSION

In this paper, we have proposed a granular model of LO for the adaptability and the re-use of the learning contents. This model of content is designed respecting to the various characteristics of the stated granularity. The first advantage of this model is its hierarchical structure in the form of "grains" of contents which respect the specifications of the existing standards (LOM, SCORM, etc.). Another advantage lies in the fact that the same fragment or a multimedia brick could easily be re-used in several documents or then directly in another context of learning. We can also note that the model suggested is open. It can indeed employ the proprietary format of the contents, or import it from the web. Moreover, the granularity combined with indexing plays an important role in facilitating the search mechanism and adaptability. Indeed, instead of adding metadata to large blocks of educational content, small size granules are indexed, which enlarges the search space. This will also destroy the silence of search, which may be due to an insufficient granularity.

As a second point, we have showed an architecture system able of integrating the LOs infrastructure, the domain concept structure and the learner model interface. Different interfaces are presented.

It is clear that several issues remain to be addressed to arrive at the expected system. Our work continues along these lines to try to finish a first functional prototype which will be tested and validated.

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