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Combining Individualization and Intuitive Guided Learning through Compound Learning Resources

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***Abstract*—Individualized teaching approaches try to find the best sequence of learning resources capable of satisfying individual goals and preferences. On the other side, intuitive guided learning approaches see the learning experience as "non-linear": each learner can chose a personal path across the material according to his/her interests and preferences. In this paper we present a method and a prototype able to combine the advantages of both approaches by introducing the concept of "compound learning resource": a complex didactic artifact bringing together multiple semantically connected learning resources that can be freely browsed by the learner. Included semantic connections have a twofold function: from one side they guide the learners' navigation, from the other side they allow the dynamic reconfiguration of the resource according to learners' needs and preferences (individualization). Experimental results with real users in a University context are also presented.**

Keywords—individualized teaching, typed links, intuitive guided learning, semantic link networks

I. Introduction

It frequently happens that the complex nature of a course prevents teachers to easily find a correct, fluid and comprehensive sequence of learning resources able to fit any learners' need. This can be due to a lack in learner mental structures (arising from a lack of knowledge about concepts that are object of teaching or their prerequisites) or because of their own learning style. This may result is an inefficient learning experience.

The problem can be overcome through *individualized teaching* approaches seeing learning as a "journey" that is different for each learner [1]. Such approaches are aimed to select the best sequence of learning activities a learner must perform to reach a given learning goal taking into account his/her capabilities, knowledge and preferences.

Individualized teaching is used for developing personal learning programs and to engage learners in the learning process so that learners' learning potentials and success can be optimized. On the other side it tends to "force" the learner to follow a fixed, optimized, sequence of activities allowing few crossing possibilities [2].

Intuitive guided learning approaches try to solve the same problem in a different way. Instead of forcing down learners in a particular course of action, they configure the surrounding pedagogic design in order to guide them towards learning objectives in an unobtrusive fashion. One of the most important characteristics of such pedagogy is that the experience is non-linear: "guided" (as an antonym of "forced") implies that the learner can deviate from the intended path through the learning experience [3].

Intuitive guided learning approaches are particularly suitable for *digital natives* that consider this modality of interaction as more natural and stimulating than sequential reading [4]. They are typically curious and driven by the pleasure of discovering something new within the learning material. In these learners, learning happens in a incidental manner, through the exploration and the finding of a personal key of content understanding.

The purpose of this paper is to define a method that tries to combine the advantages of both individualization and intuitive guided learning. The defined method is able to generate optimized, non-linear learning experiences that can support multi-perspective learning by discovery but, at the same time, are individualized on each learner.

To this aim we introduce the concept of "compound learning resource": a complex didactic artifact that brings together multiple semantically connected resources that may be browsed in different ways. Semantic connections guide the learner during the resource navigation providing hints about what he/she will see next. According to [5], this improves the navigation effectiveness.

Semantic connections are also used to adapt compound learning resources with respect to teaching and learning preferences i.e. to create different views of the same resources to suit different needs. According to [6], this enables to balance *scaffolding* (i.e. the adoption of specific "structures" in the form of "interpretation keys" to follow) and *fading* (i.e. the decrease in using such structures when the learner shows a greater autonomy).

The paper is organized as follows: the second section introduces some existing work related to this research, the third section describes the proposed approach from the theoretical point of view, the fourth section presents the developed prototype whose experimentation with real users is summarized in the fifth section. The last section presents conclusions and planned future works.

II. Related Work

A *typed hyperlink* [7] in a hypertext system is a link to another document or part of a document that includes information about the character of the link. This allows a

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user to take actions such as searching only certain types of links or displaying them differently.

Typed links were a common feature in pre-Internet hypertext systems but the lack of standardization has always hindered their use beyond prototype systems. The version 4 of the HTML standard supports typed links using the *rel* (forward) and *rev* (reverse) attributes to *<link>* and *<a>* tags.

In [8] a Semantic Link Network (SLN) is defined as a directed network consisting of nodes and semantic links. A node can be a concept, an instance of concept, a schema of data set, a URL or any form of resource. A semantic link reflects a kind of relational knowledge represented as a pointer with a tag describing such semantic relations as *equal*, *causeEffect*, *implication*, *subtype*, *similar*, *instance*, *sequence* and *reference*.

Compared with the classical hyperlink structure, typed links have several advantages in supporting e-learning because they foster inductive and analogical reasoning, help to understand new semantic relations and can inspire creative thinking and broaden the knowledge of learners.

Typed hyperlinks between learning resources find their motivation in the theory of *Ausubel* [9] and on the distinction between learning "by rote" and learning meaningfully. When we learn by rote, we relate new ideas in cognitive structures with existing ones without effort. In contrast, when we learn meaningfully, we have to integrate new concepts in specific ways with ideas and propositions already existing in our cognitive structures.

In the latter case, typed hyperlinks are able to drive and support learning. These relations can act as advance organizers to facilitate the integration of new concepts and ideas with the relevant existing knowledge [10]. In this way it is possible to obtain from the learner a correct "learning behavior" that put him in a position to achieve the learning goals in a controlled and directed way.

A first list of relations between learning resources is proposed by *Dublin Core* [11] for the annotation of digital resources and is integrated in the IEEE LOM standard for the annotation of learning objects. This standard proposes the following 6 relations (including reverses): *hasVersion*, *Replaces*, *Requires*, *hasPart*, *References* and *hasFormat*.

Further studies extend these standard relations from the pedagogical viewpoint. As an example, the *Educational Rationale Metadata Initiative* [12] has defined metadata to represent process-oriented information about instructional approaches for learning resources.

Several adaptive e-learning systems exist that exploit semantic connections and hyperlink adaptation [13]. As an example, the *AHA!* system employs fragment and link hiding to adapt courses. *INSPIRE* offers instead adaptive link annotation and sorting as well as adaptive curriculum sequencing techniques to guide learner through a learning space using a path respecting his learning style.

InterBook is a tool for creation and presentation of adaptive electronic textbooks. It offers adaptive link annotation and direct guidance as well as automatically generated glossaries and indexes. *NetCoach* simplifies the course authoring process by offering the possibility to insert content and define relations between documents using concept networks. Adaptive annotation of links and curriculum sequencing features are also supported.

ALE is an environment for creating adaptive courses. It tracks students' progress through the course and annotates links using this information. *Knowledge Sea* tries to help students with navigation to additional outside content by providing adaptively annotated links based on the topics and recommendations from other students.

MetaLinks is a system for creating adaptive electronic textbooks. The system monitors a student's path through the content and provides adaptive annotation of links telling the student if all prerequisites for a given page have been met or not. *QuizGuide* helps students to select the most relevant examples through adaptive annotation to links to problems. Links are annotated on the basis of known prerequisites and relevance of the current topic.

III. THE PROPOSED APPROACH

Compound Learning Resources (CLRs) can support adaptation and intuitive guided learning thanks to embedded semantic connections. They are structured as dynamic hypertexts where content is organized in pages and navigation among pages is user-driven.

Connections can link satellite resources to a kernel and learning resources together. To this purpose we defined a *semantic connection model* to describe the kind and the meaning of each available connection. Connections can be dynamically and automatically activated and deactivated basing on teaching and learning preferences. To this aim we also defined a *CLR adaptation methodology*.

The following subsections describe in more details the defined semantic connection model as well as the related resource adaptation methodology. Before describing these theoretical components, we introduce IWT (Intelligent Web Teacher), a learning environment that we have used as starting point of our research.

A. The Starting Point

CLRs have been implemented within IWT, a complete e-learning system based on individualization principles. IWT can generate personalized learning experiences [14] by relaying on four interacting models as described below.

The *domain model* describes the knowledge that is object of teaching through a set of concepts (topics to be taught) and a set of relations between concepts.

The *learner model* represents a learner and includes the *cognitive state* (representing the knowledge reached by a learner at a given time with respect to domain concepts) and a set of *learning preferences* (providing an evaluation of which learning strategies are more feasible for a given learner). Both components are automatically evaluated by the system by analysing learners' behaviour.

The *learning resource model* represents a learning resource and is based on the application of the IEEE LOM standard. It includes the set of concepts that are covered by the learning resource and an additional set of didactical properties representing applied learning strategies.

The *unit of learning model* represents a sequence of learning resources needed for a learner to understand a set of target concepts. A set of *teaching preferences* can be linked to this model to define feasible teaching strategies that should be applied within it. In [15] we have described the generation of a unit of learning starting from a set of target concepts and from a learner model.

By leveraging on these models, IWT supports a learner centred approach and is able to build the best sequence of learning resources for each learner starting from a given set of target concepts [16]. In the next subsection we describe how CLRs are able to enrich these functions by adding intuitive guided learning capabilities.

B. *The Semantic Connection Model*

The semantic connection model formally describes a connection inside a CLR. Model components are described in table I. As defined by the *Scope* parameter, connections can be applied to the whole resource (page connections) or to parts of it (text connections).

TABLE I. COMPONENTS OF THE SEMANTIC CONNECTION MODEL

Name	Description
Type	It specifies the nature of the connection. It is composed by three sub-parameters: *group*, *name* and *color*. Two groups of connection types are supported: connections *between* and *within* learning resources.
Scope	It specifies the part of resource text on which the connection is applied. If blank it applies to the whole resource.
Optionality	It specifies if a connection is optional or mandatory. Only optional connections can be removed by the resource adaptation methodology.
Tooltip	It is a text purposed to provide a brief description of the connected content and is shown to the learner when he places the mouse pointer over the connection activator.
Target	It is the target content to be shown when the connection is clicked by the learner. The target content can be internal (i.e. another page uploaded by the teacher on another IWT resource) or external (i.e. a Web resource reachable through an URL).

Concerning the *Type* parameter we have defined two groups with different meanings: *connections between learning resources* are purposed to link learning resources together while *connections within* a learning resource are purposed to link resource pages to a resource kernel.

Starting from the literature review summarized in II, we have filled these groups with meaningful relations. By exploiting results coming from the *Rhetorical Structure Theory* [16] that have been used also for *Learning Objects Networks* [18] we propose, for the first group, the list of connection types reported in table II.

Connections within a learning resource are generally purposed to enhance the educational intentions underlying the architecture of a learning resource. Several studies can guide to the identification of feasible typologies for this kind of connections. In particular we started from the *Theory of Conditions of Learning* [19] and mixed tags from the *Educational Rationale Metadata Initiative* [12] to obtain the list of connection types reported in table III.

The CLR obtained through the application of the defined semantic connections model has a graph-like structure as the sample shown in figure 1.

TABLE II. CONNECTIONS BETWEEN LEARNING RESOURCES

Name	Description
Elaboration	The referenced resource elaborates the content of the described resource or of a part of it.
Evidence	The referenced resource provides information to increase the belief in the claim mentioned in the described resource or in a part of it.
Interpretation	The referenced resource interprets or explains the described resource or a part of it.
Justification	The referenced resource justifies the described resource or a part of it.
Summary	The referenced resource summarises the described resource or a part of it.
Contrast-Opposite	The content of the described resource (or a part of it) and of the referenced resource are opposites.
Condition-Restriction	The referenced resource limits the content of the described resource or of a part of it.
Restatement-Alternative	The referenced resource provides an alternative of presenting the described resource or a part of it.
Sequence	The referenced resource is the sequence or chronology of the described resource.

TABLE III. CONNECTIONS WITHIN LEARNING RESOURCES

Name	Description
Motivation	The referenced content strongly motivates and justifies the importance of the topic explained in the described resource or in a part of it.
Critique	The referenced content presents a critical review of the issues included in the described resource or in a part of it.
Collaboration	The referenced content includes spaces for discussion or cooperation about the topic described within the described resource or a part of it.
Engaging	The referenced content leads students to discover the validity of what they are studying by displaying bad behaviours held by those who do not know the topic explained within a resource or a part of it.
Integration	The referenced content is purposed to deepen (from several viewpoints) the theme explained in the described resource or in a part of it.
Anchor	The referenced content is purposed to anchor the knowledge explained in the described resource (or in a part of it) within an authentic context.
Perspective	The referenced content explains the knowledge provided by the described resource (or by a part of it) from a different perspective.

C. *Compound Learning Resource Customization*

Semantic connections in CLRs can be automatically hidden with respect to teaching and learning preferences.

As described above, in IWT teaching preferences are linked to the unit of learning model to define feasible teaching strategies for it. They are represented as an application $TP\ (Props \times PropVals) \rightarrow [0, 10]$ where *Props* is a set of didactical properties and *PropVals* is the set of feasible values for such properties.

To support CLR adaptation, a new property is added named "allowed connections" or *all-conn* whose feasible values are those reported in tables II and III. Allowed connections for a unit of learning can be so specified by teachers during course design.

As described above, in IWT learning preferences are linked to the learner model to evaluate learning strategies that may be adopted for a learner. They are represented as an application LP ($Props \times PropVals$) $\rightarrow$ [0, 10] where *Props* and *PropVals* have the same meaning of before.

To support CLR adaptation, a new kind of property is added named "preferred connections" or *pref-conn* whose admitted values are those reported in tables II and III. Preferred connections for a given learner will be inferred by the system through an algorithm that analyses his behavior during the CLR navigation.

First of all, when a new learner model is created, the value of *LP* (*pref-conn*, *c-type*) is initialized to 5 for each type of connection *c-type* (i.e. for each value reported in tables II and III). This means that, initially, all connections are equally preferred. Then, each time a learner completes a CLR, a modifier $mod_{c\text{-}type}$ is calculated for each *c-type* for which at least a connection in the resource exists:

$$mod_{c-type} = \frac{\sum_{c \in conn-type} toggle_c}{|conn - type| \cdot counter}$$

where *conn-type* is the set of resource connection whose type is *c-type*, $toggle_c = 1$ if the connection c has been followed by the learner and -1 otherwise and *counter* is the number of times the user accessed this CLR till now.

This means each time a learner follows a connection, the preference for the related type is increased while each time an existing connection is skipped, preferences for the related type are decreased. The level of increase/decrease depends on the number of connections of that kind that are available in the resource as well as on the number of time the learner accesses a learning resource (i.e. connections accessed the first time produce greater modifications with respect to the following accesses).

Once the modifier is calculated for all connection types after a compound learning resource fruition, the new value for *LP* (*pref-conn*, *c-type*) is then calculated in this way:

$$max\ \{min\ \{LP\ (pref\text{-}conn, c\text{-}type) + mod_{c\text{-}type}\ , 10\}, 0\}$$

so adding the modifiers to the learning preferences of the learner model but limiting the result between 0 and 10.

By knowing *LP* and *TP* for each available connection type it is possible to apply a CLR adaptation algorithm working in this way:

- remove from the resource *optional* connections of type *c-type*, if *TP* (*all-conn*, *c-type*) $< \theta_1$;
- remove from the resource optional connections of type *c-type*, if *LP* (*pref-conn*, *c-type*) $< \theta_2$;
- reorder page connections following the decreasing order of *LP* (*pref-conn*, *c-type*).

Constants θ_1 and θ_2 range from 0 to 10 and are settled experimentally. The algorithm is executed each time a resource is accessed by the learner. In fact, while function *TP* doesn't change for a given course, *LP* may change throughout the course according to the learner behavior.

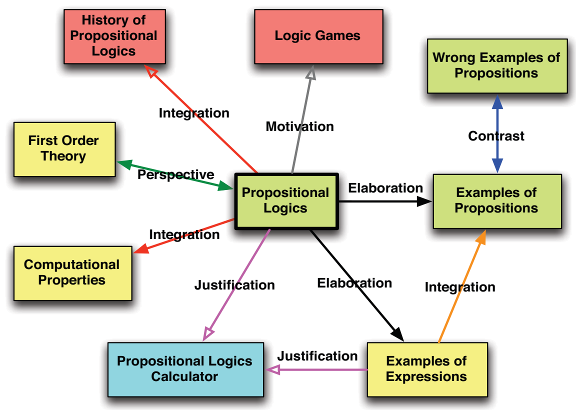

Figure 1. The structure of a compound learning resource.

IV. THE DEVELOPED PROTOTYPE

The IWT logical architecture is divided in four main layers. The first layer is the *framework* used by developers to design and implement other IWT components. The second layer is composed by *core services* providing basic features for the management of users, roles, resources, metadata and domains as well as for user profiling and learning personalization.

The third layer is composed by *application services* used as building blocks to compose e-learning applications for specific domains. They include blocks for content management, learning and ontology management as well as for communication and collaboration. On the top of the stack, *learning applications* covering specific scenarios obtained as integration of application services are built.

IWT server side components are developed in .NET technology and use Microsoft SQL Server for persistency. IWT is an extensible system both at the level of learning resources (with drivers i.e. software components able to edit, manage and deliver a specific kind of resource) and at services level (with plug-ins i.e. software components providing new back-end services). To integrate CLRs in IWT a set of additional components have been designed and developed as depicted in figure 2.

As shown in the figure, we extended existing models' storing and retrieving services to support the semantic connection model defined in III.B. Also data structures for learning and teaching preferences have been extended to add preferences about semantic connections.

Within the *application services* layer, we implemented and integrated a *CLR Manager* dealing with the design and the execution of CLRs. Such component is composed by two sub-components: a designer and an editor.

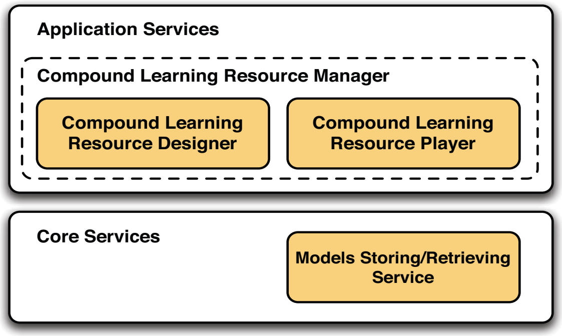

Figure 2. Developed components within the IWT architecture.

The *designer* allows teachers to edit and connect pages of a CLR. It is based upon a *WYSIWYG* hypertext editor enriched with the chance to specify additional parameters for each defined hyperlink according to the model defined in III.B as well as to add page connections rather than only text ones (see figure 3). The *player* allows learners to execute a CLR and implements the adaptation algorithm defined in III.C. The figure 4 shows the player embedded within an IWT unit of learning whose sequence of learning resources to follow is represented on the left side.

Learners start the navigation from an index page and may follow connections between and within the resource. Pieces of text that activate a connection are highlighted with different colors according to the connection type. Page connections appear on a vertical bar on the right side of the resource as colored boxes (color is chosen according to the connection type).

When a page differs from the index, a back connection (shaped a colored triangle) is added to the right side bar in order to navigate the connection backward. Once a learner puts the cursor over highlighted text or a colored box, a textbox appears indicating the kind of connection and showing the tooltip text defined by the teacher.

V. PROTOTYPE EVALUATION

In order to evaluate the effectiveness of CLRs and analyze their effects in the learning process, we involved 68 University students enrolled in an on-line course about *Software Engineering* where one topic, *Requirements*, was modeled both with a standard lesson and with a CLR.

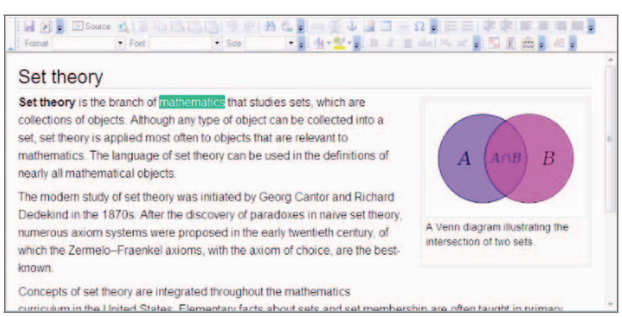

Figure 3. User interface of the CLR designer.

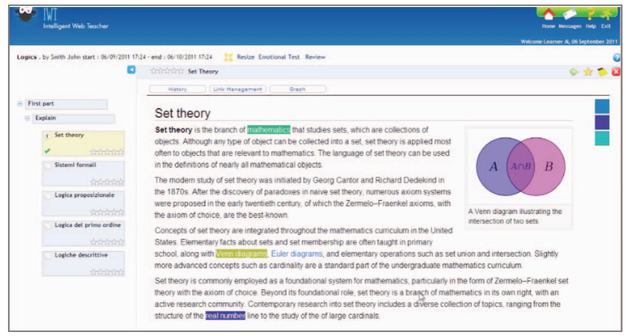

Figure 4. The CLR player embedded in IWT.

All students had to follow the on-line teaching plan, learn the mandatory material and perform planned learning activities. Concerning the *Requirements* topic, students had the possibility to chose to learn through the standard lesson or through the CLR. Students selecting the second option, had to fill a questionnaire to be submitted at the end of the experiment.

As the study focused on possible improvements to be made on CLRs, the questionnaire was aimed at evaluating both students' satisfaction and system user-friendliness. In particular, open and closed questions were used to evaluate students' satisfaction while the System Usability Scale [20], based on answers given on the 5-point *Likert* scale, was used to measure user-friendliness.

Concerning students' *satisfaction*, after calculating the 0-10 scale for each student we got an average of 6.59 (SD=2.17, Md=7). This result is very good considering that the CLR-type resources are still in research evolution. Students in general liked CRLs and semantic connections.

They found these very useful for their study (M=7.08, SD=2.87, Md=8.5). Most of them (above 75%) indicated that the semantic connections allowed them to go deeper and faster into additional information without having to search for this extra information by themselves.

The average obtained score for *usability* was 60,78 on a scale ranging from 0 to 100. This is not very high but quite promising considering that the tool is still in a prototypal stage. Despite that, many students found the CLR easy to use (M = 3.44, SD = 1.00) and most of them learned to use CLRs very quickly.

All students participating in the experiment were also tested at the end of the course with respect to all course topics, including *Requirements*. Obtained scores were then compared with scores obtained by student that didn't participate in the experiment (control group).

The assessment was performed by a lecturer who used a standard 10-point scale to score the students' answers. As reported in table IV, students from the experimental group scored higher than the control group. Interestingly, the Standard Deviation (SD) in the experimental group is consideratly lower than in the control group.

In summary we conclude that, even if some work remains to be done in order to improve their usability, students liked CLRs and found them interesting to extend their learning by means of the semantic connections. In addition, the levels of competences acquired by using a

CLR, denoted that the use of semantic connections within the resource contributed to improve the understanding of course key concepts.

TABLE IV. SUMMARY OF EXPERIMENTATION RESULTS

	Experimental Group	Control Group
Participants	41	27
Overall Satisfaction *Questionnaire (range: 0-10)*	M = 6,59 SD = 2,17 Md = 7	
Usability *SUS Score (range: 0-100)*	60,78	
Student Performances *Assessment (range: 0-10)*	M = 7,83 SD = 0,78 Md = 8	M = 6,33 SD = 1,28 Md = 6

VI. CONCLUSIONS AND FUTURE WORK

This paper describes a research aimed at the definition of CLRs: kind of learning resources that tries to combine the advantages of individualization as well as intuitive guided learning. CLRs are optimized, non-linear learning resources that can support multi-perspective learning by discovery but, at the same time, are individualized with respect to preferences of each learner.

To support CLRs, we defined a semantic connection model and a CLR adaptation algorithm. Basing on such theoretical components, we developed a prototype CLR designer and a player tools, and integrated them in an existing e-learning system. We then experimented such system, including CLRs, with real users within an on-line University course obtaining promising results.

Starting from experimentation results, our future work will focus on the provisioning of a more user friendly interface both to students (during the delivery phase) and to teachers (in the authoring phase). To this second aim, we are currently designing an easy-to-use interface based on graphs manipulation for resources editing.

Moreover we also envisage some improvement in the semantic connections model with a rationalisation of supported connections exploiting teachers' feedback as well as an enrichment of adaptation capabilities by adding a recommendation component able to exploit not only the previous behaviour of the current learner but also available information about learners with similar profiles.

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