# Dynamic Course Editor to Train Electric Power Operators

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***Abstract*— An SCORM compliant system called Aprend-e (e-learning in Spanish) has been developed and implanted at Comisión Federal de Electricidad (CFE) to build a collection of training objects for electric power operators. Aprend-e includes an editor and a repository of learning objects (LOs). LOs prepared with the editor have been executed with a SCORM compliant LMS with positive results. The editor is implemented using a graphic interface and a semantic network, such that an instructor authoring a LO can use any of all possible statements of the SCORM 2004 to build a manifest for the LO. For instructors that develop dynamic courses or intelligent tutors, Aprend-e has adapted a method from the literature were the course planning can be represented using a graph (AND/OR graph) and then the graph is converted to SCORM activity trees. Currently the repository has been loaded with 130 LOs for electric power operators training.**

***Index Terms*— tutorial systems, planning, virtual reality, learning objects, industrial application***

## I. INTRODUCTION

Derived from governmental policies related to training management and considering its strategic planning objectives, CFE (Comisión Federal de Electricidad – the National Electric Utility in Mexico) has establish an strategic program to improve its human capital and to align it with its mission and future vision. CFE is responsible for generating, transmitting and distributing electricity through out the Mexican nation.

As part of this program, CFE has generated an ambitious program for learning and training of personnel. The training impact is directed on the production efficiency increase and in the decrease of non-planned production equipment outages and failures. The constant technology changes make it necessary a permanent training of the CFE personnel. In general, the traditional training systems are used: classroom instruction, laboratory practices, workshops, training in specialized simulators, organized seminars, and short courses lectured by specialists, and annual congresses like IEEE, CIGRE, etc.

These training traditional systems have shown effectiveness and consistency for decades. However, CFE has a clear view of its training needs according with its expansion plans and modernization; some actions are mentioned as follows [1]:

- Construction of a collection of 150 Job Skills Technical Standards (JSTS).
- To have the distance training technology consolidated, including the technological infrastructure (local networks, Internet and Intranet) and the design of courses (self-instruction and traditional) to satisfy the requirements of the JSTS.
- To have an environment with a suitable training from a pedagogical and affective viewpoint to certify personnel in knowledge, skill, expertise, abilities and attitudes for operation of power systems.

The training requirements for utilities ask for powerful interfaces, a more efficient and better adaptive training, by means of incorporating artificial intelligent (AI) techniques, adaptive interfaces, simulation tools, learning objects based on multimedia and virtual reality components.

Intelligent Tutoring Systems ITS [2] are interactive learning environments that have the ability to adapt to a specific student during the teaching process. In general, the adaptation process can be described by three phases: (i) getting the information about the student, (ii) processing the information to initialize and update a student model, and (iii) using the student model to provide the adaptation.

After a summary of the architecture of the SCORM complaint intelligent environment Aprend-e for the training of power systems operators presented in [3], this paper describes in detail one of the components of Aprend-e, the Domain Knowledge Module. In contrast with a traditional training system, the main goal of this intelligent environment is to certify operators in knowledge, skills, expertise, abilities and attitudes for operation of power systems.

## II. ARCHITECTURE OF THE INTELLIGENT ENVIRONMENT APREND-E

The architecture of the intelligent environment Aprend-e is based on dynamic course generating systems proposed by Brusilovsky [4]. The intelligent environment is composed of four main components (see Figure 1): the domain

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knowledge module, the tutor, the operator model, and the learning management system (LMS).

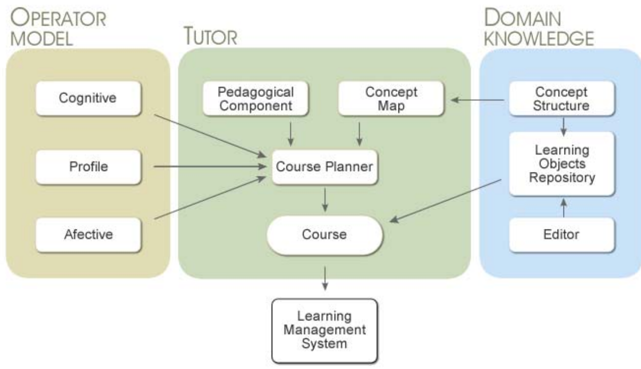


Figure 1 Architecture of SCORM complaint intelligent environment Aprend-e

The first module contains the domain knowledge as learning objects and concept structure maps. The Learning Objects are built using the Editor en stored in the Learning Objects Repository; the maps are SCORM complaint activity trees also constructed using the Editor.

The tutor module is the component that contains the sequence of learning objects to be presented to an operator as a self instructional nontraditional course. The LMS generates this sequence which is represented as an adapted SCORM activity tree for each specific operator.

The operator model is additionally used to adapt the activity tree to each specific operator. The operator model is divided into three subcomponents: cognitive component, operator profile and affective component [5]. The LMS controls the interactions with the operator, including the dialogue and the screen layout. The main purpose of an LMS is to present to the operator the learning materials in the most effective way.

## III. Domain Knowledge Module

The domain knowledge module has three main components: the concept structure map, the editor and the repository of learning objects. The domain knowledge contains the expert's operation abilities in procedure and malfunction operations and its representation considers both theoretical and practical concepts.

### *A. The concept structure map*

The concept structure contains the concept/topic structure of the subject knowledge to be taught (see figure 2). It is possible to organize the domain concepts/topics into a set of smaller, possibly interrelated AND/OR graphs, representing relatively independent sub-areas of the knowledge, different views, or different levels of granularity. A concept structure is represented as an AND/OR graph, where nodes represent the domain concepts or elements of knowledge, such as electrical topics, components of control board, rules, procedures and so on; and arcs represent relationships between concepts, such as a prerequisite for learning a concept or a sequence. Every node is associated with a set of teaching or testing materials labeled as Reusable Learning Objects (RLO), which instantiate different ways to teach a concept/topic (e.g. introduce, explain, give an example, and give a simulation, exercise, or test).

For the training of power plant operators, the concept structure map is made based on the structural decomposition of the electricity generation process. The generation process can be divided in unit, structure, systems, subsystems, equipment and component. The concept structure has a higher expressive power because it allows representing not only prerequisites, but also many different types of relationships between concepts; and it enables the use of AI planning techniques for the generation of alternative courses. Therefore, it guarantees a wide variety of different teaching goals and several courses for achieving these goals.

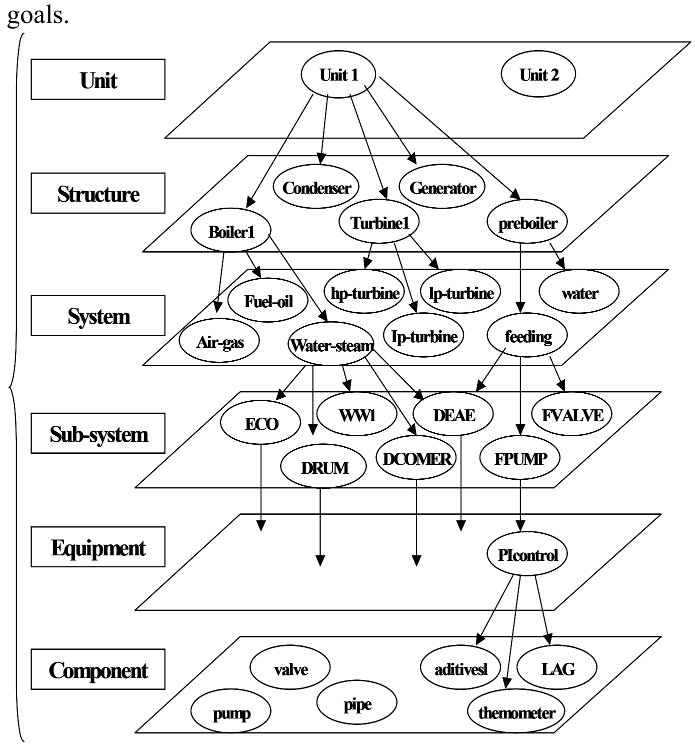


Figure 2 Concept structure map for training of power plant.

### *B. The editor*

The editor contains tools for edition of teaching and testing materials to produce learning objects. These learning materials consider both theoretical and practical concepts contained in electronic books, simulation tools, multimedia presentations and virtual reality objects, to present to the operator pedagogical actions such as explanations, exercises, tests, and so on. Each material is labeled as Reusable Learning Object (RLO) or Shared Content Object (SCO) according with the SCORM (Sharable Content Object Reference Model) terminology [6]. Learning objects are self-contained learning components that are stored and accessed independently. RLO are any digital resource that can be reused to support Web-based learning using learning management systems (LMS). The authors or learning developers can create, store, reuse, manage and deliver digital learning content. The same object may be used as many times and for as many purposes as is appropriate.

The learning objects are either dispensed to users individually or used as components to assemble larger learning modules of full courses, depending on individual learning needs. The instructional output may be delivered via the Web, CD-ROM or printed materials. Lately, work has been done at CFE to create a valve maintenance course and an energized power-line maintenance course using RLO based on virtual reality [7]. Also, and only for the generation process, CFE has a collection of more than 130 instructional courses developed in house during the last 10 years integrated to the Domain Knowledge Module.

The editor allows the repository manager to take learning content, generate a SCORM 2004 compliant label o manifest and to compress all together in a zip file (see Figure 3). The result is a SCORM compliant Learning Object (SLO) that can be managed by any SCORM compliant LMS.

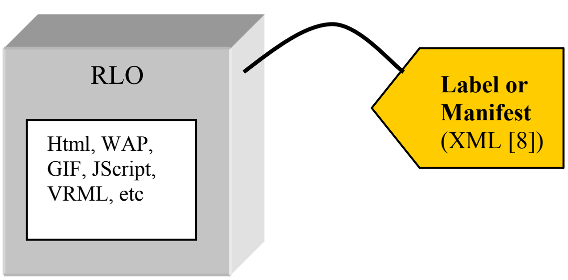


Figure 3 SCORM compliant Learning Object (SLO)

The SCORM compliant manifest contains metadata for the classification and recovery of the SLO. The classification categories have been extended to satisfy the needs of CFE, some were inspired from Figure 2. The nine categories of SCORM meta-data elements are: *General, Life Cycle, Meta-metadata, Technical, Educational, Rights, Relation, Annotation, and Classification.* This classification is extended with new categories as follows.

**Activity branch**, it identifies established criteria according to the labor contract.

**Specialty**, the department, area or worker's function with acquired specialty along their labor life.

**Process**, generation, transmission, control, distribution, or support processes (management).

**Equipment**, the equipments are classified as main, auxiliary and miscellaneous according to their importance in the electric generation process.

**Career Plan**, it is the functional position in the activity branch and specialty in which the worker is currently assigned and that he can ascend in terms of his knowledge, abilities and attitudes or demonstrated competence.

**Functional position**, it identifies the role of the worker's formation in his current position and immediate higher position according to his career plan.

**Course type**, it is institutional, foundation, development, or others. A course type is also self training or traditional.

**Activity type**, it is traditional or distance learning.

**Department**, it is the workspace according to the conceptual and functional organic structure.

**Functional level**, Directives, controls means, supervisors and operative.

The SLO is a set of items to structure a course, workshop, or other aggregation of learning resources; the organization of the SLO or activity tree is as shown in Figure 4.

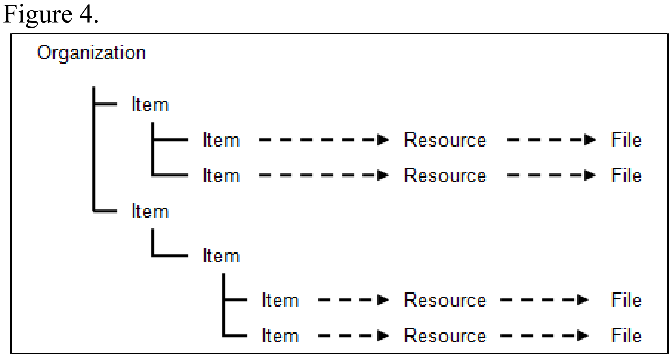


Figure 4 the organization of an SLO

In case that the course is dynamic, adaptive or intelligent tutor, one possibility is that the initial specification of the SLO is represented as an AND/OR graph as mentioned above. An example of an AND/OR graph representing a dynamic course taken from [4] is show in figure 5.

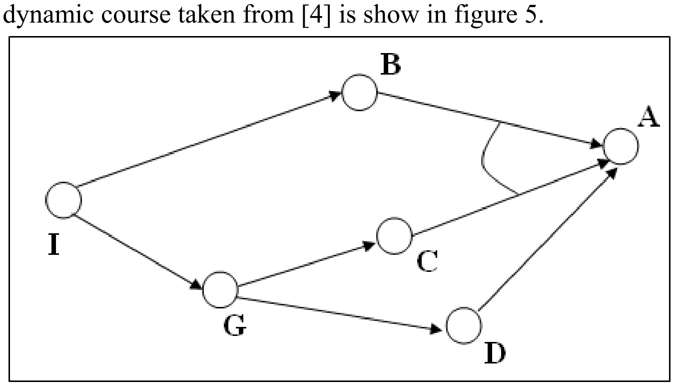


Figure 5 AND/OR graph representing a dynamic course

The Domain Structure contains the concept/topic structure of the subject knowledge to be taught. It is represented as an AND/OR graph. The nodes represent the elements of knowledge (concepts, topics, rules etc.). If two nodes B and C are connected with a third one, A, with an ‘AND’ arc, this means that both nodes B and C have to be taught when following the arcs to A. Otherwise, they would be considered as alternatives, i.e. there is a choice of nodes to be taught, either B or C. The arcs in the graph represent relationships between the concepts. These relationships can have various semantics. For example, if nodes B and C are connected with node A with an AND-relationship of type ‘aggregation’, this means that C contains sub-components B and C. If they are connected with an OR-relationship of type ‘generalization’, this means that A is a general concept with possible instances B or C. There are many other possible semantic relationships, for example, causal, temporal, analogy, simple prerequisite, etc.

Using an approach based on the classical artificial intelligence AO* procedure, the AND/OR graph can be converted to an activity tree as shown in figure 6. The activity tree of figure 6 resembles the organization of an SLO of figure 4 and can be coded and packed to be managed by any SCORM compliant LMS.

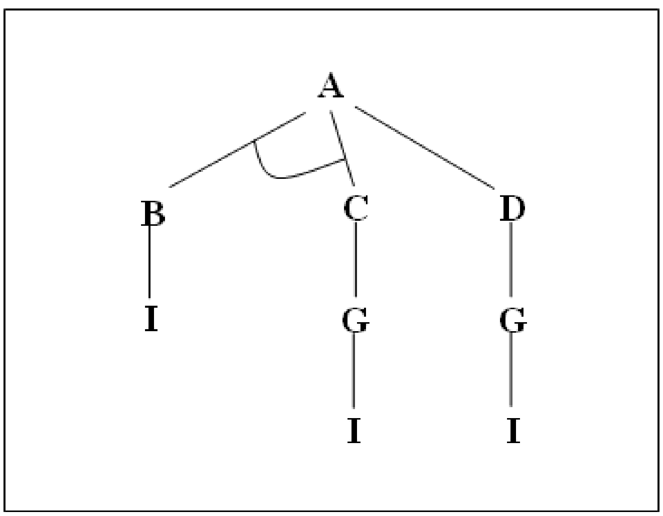


Figure 6 An activity tree for the AND/OR graph of figure

The editor has an interface with the instructor an a presentation manager that allows the user to search the repository for a SLO that fits his needs, and once the user selects a SLO, the system presents the SLO index and the user can display the learning content objects using hyperlinks to these resources as show in Figure 7.


Figure 7 An actual screen showing an SLO organization

*C. Learning object repository.*

The Domain Knowledge module has a Learning Object Repository (LOR). The LOR is a central database in which learning content (SLO) is stored and managed (see Figure 8). The Repository main component is the database.

The repository is implemented using a relational database management system and an abstraction model of the database using a semantic network is shown in Figure 9. Other authors [8] use an ontology to model the database but in this case a semantic net is simpler and is a closer representation of the relational database. The learning objects are packed and an SCORM compliant LMS can access them through the Web using either an HTML page or a Web service [9]. The organization component of the manifest is a sequencing map that the LMS uses to present to the trainee the different learning items. Each item has objectives to be satisfied and rules to evaluate if a tree of learning items in the organization is completed by the student or not. Also, rules are used to allow the trainee to follow a different order than the linear top-down left-to-right order and skip items if he shows that he already has the appropriate competence to satisfy the objectives of the items to be skipped.

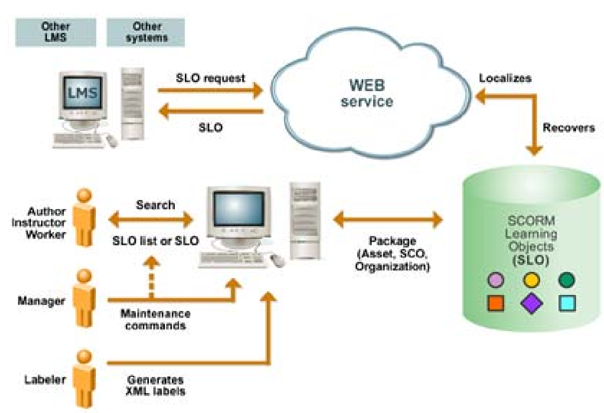


Figure 8 The environment for the Learning Object Repository

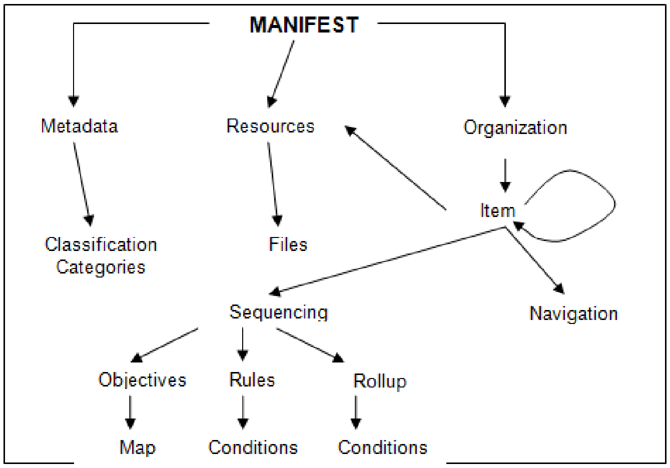


Figure 9 The semantic network for the database structure

By the end of the year 2008, the database is loaded with 130 power plant courses wrapped as SCORM complaint Learning Objects. The repository can be accessed nation wide through Intranet.

## IV. CONCLUSIONS AND FUTURE WORK

In this paper we have presented the architecture of Aprend-e, an Intelligent Environment for training Power Systems Operators. One of the components was described: the Domain Knowledge Module that contains a Learning Object Repository. The concept structure map of a power plant domain, where the nodes represent concepts of the domain and the links relationships between concepts was used as the basis to build the semantic network that supports the storage and retrieval of SCORM compliant Learning Objects (SLO).

Currently, the repository is loaded with 130 power plant courses wrapped as SLO and it is fully operating at CFE.

The intelligent tutor module based on course planner is included as part of the operation of any SCORM LMS. The operator models based on cognitive and affective components are under development and are going to be integrated to Aprend-e.

The Intelligent Tutor representation used in this paper is the AND/OR graph, other representations as probabilistic models [5] are to be developed and tested using the Aprend-e system.

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