An Architecture for an Adaptive and Collaborative Learning Management System in Aviation Security

Yi Guo, Adrian Schwaninger
Department of Psychology
University of Zurich, Switzerland
{y.guo,a.schwaninger}@psychologie.uzh.ch

Harald Gall
Department of Informatics
University of Zurich, Switzerland
gall@ifi.uzh.ch

Abstract

The importance of aviation security has increased dramatically in recent years. Frequently changing regulations and the need to adapt quickly to new and emerging threats are challenges that need to be addressed by airports, security companies and appropriate authorities across the world. Learning Management Systems (LMS) have been developed as effective tools for enhancing the management, integration and application of knowledge in organizations. In the aviation security domain, we need mechanisms to quickly adapt to new learning content, to different roles ranging from screeners to supervisors, to flexible training scenarios and solid job assessments. For that, a learning system has to be flexible and adaptive both in knowledge, organizational and in collaboration dimensions. Current LMS do not meet these requirements. In this paper we present a software architecture that is apt to support the adaptability and collaboration needs for such a system in aviation security. We discuss the requirements, roles, learning objects and course configuration in terms of adaptive and collaborative learning. We present a six-layer architecture and discuss some of its application scenarios. Our aim is to improve the quality and usefulness of LMS in aviation security by utilizing knowledge-based analysis for data analysis and integrating a process engine for collaborative learning. We briefly report on our prototype and the gained first feedback from the users.

1 Introduction

Recent aviation security regulations define stringent requirements for baggage and passenger screening at airports. Since these rules change quite frequently, airport administration departments around the world are in need of flexible knowledge and learning management systems to train their security personnel (e.g. screeners, supervisors, etc. often of different security companies). Such systems can also be very useful to provide means for quickly adapting to new and emerging threats. In research, some recent approaches [10, 11, 13] focus on security personnel training to impart necessary skills to screeners for preventing terrorism and smuggling. Learning Management Systems (LMS) are one means to structure knowledge about security threats and skills of personnel. However, aviation security (AVSEC) has high demands for flexibility and sustainability of training. As a consequence, training and re-training are essential for a successful system. Since knowledge evolves quite rapidly an LMS for AVSEC also needs to be adaptive both to new learning contents and to effectively improve skills of all kinds of learners. These particularities include high security access control, frequency of updating and implication of information as well as effective re-training and job assessment. Additionally, since the learning and training takes place in many locations (e.g. airports around the world), data from these training sessions needs to be analyzed and evaluated to benefit the quality of training. Collaboration is, therefore, another important dimension when it comes to sharing and integrating the experiences and training courses of different groups of learners. Moreover, although supervisors, instructors, and screeners play different roles in the learning process, they need work in the same assembly collaboratively instead of individually to perform an adaptive learning strategy.

Current LMSs such as Saba [2], WebCT [3], Click2Learn [1] do not provide such adaptability and collaboration facilities. The standard of the Sharable Content Object Reference Model (SCORM) [5] is supported by most LMSs. SCORM enables the exchange of user data, meta-data on Sharable Content Objects (SCOs), and a variety of interaction data (e.g. choice of path, current position in the SCO, comments and annotations, duration, scores) [6]. However, SCORM only offers limited sequencing and navigation possibilities which constrains the support of LMSs [6]. As a result, collaborative learning such as peer-assessment, discussion, or self-assessment [12] cannot be supported. Further, Sharable Content Objects (SCO) can hardly impart complex facts adequately [6]. It is unable to support adaptability to changing learning and training. The shortcomings can therefore be seen both in adaptability and in collaboration.

In this paper, we propose an innovative LMS architecture to meet the requirements of AVSEC, which enhances both adaptive and collaborative functions of traditional LMS architectures. First, we describe our six layer architecture by adding collaboration functionality and knowledge-based analysis into a traditional web-based LMS architecture. Then we discuss the issue of states of learners in an adaptive learning process. These states are transformed into XML and interpreted into sequencing and navigation descriptions within a SCORM data model. Further, we describe the status of the AVSEC prototype and first feedback from the case study at one European airport.

2 Architectural Principles of AVSEC LMS

In the following we discuss the architectural principles for our adaptive and collaborative LMS for aviation security. Thereby we follow the principles of architecture description as stated in [7] and focus on all major components.

2.1 Functional requirements of LMS

We have investigated the features of the above listed LMS and distilled the following list of features that most of them provide:

- *Assessing skills and competencies of learners* is a key functionality for any LMS. This should answer the question of what kinds of skills and competencies are required for every learning goal and what kinds of skills and qualifications the trainees actually have. Both learning subjects and learning objects need to be assessed before creating learning resources.

- *Measuring gaps* should identify individuals who are best suited for a particular learning task as well as the learning gap across all participants of a particular task.

- *Managing learning resources* should enable course creation, catalogue filtering and learning resource storage.

- *Managing learning process* includes learning plan, learning strategy, learning sequence and navigation rules. An LMS should provide a pre-defined approach supporting ordering resources and recording this sequence in the form of a learning process.

- *Learning resource delivery* consists of a set of mechanisms to address resource delivery, trade-off analysis between easy access and safe control to learning resources, automatic and online messaging to course participants, transmission of joining instructions and pre-work.

- *Monitoring progress* of all participants should possibly keep up-to-date with events: who has learned what, when and what status are they in? In parallel, an auditing strategy is also required in order to correct possible misdirection.

- *Assessing results and feedback* should enable an evaluation of learning results and a re-assessment of competencies by supervisors or administrators to adjust the global or individual learning strategy for the next learning session.

2.2 Advanced functional requirements in an AVSEC LMS

However, some domains such as aviation security training require advanced features that address issues in various perspectives. For example, an AVSEC course should be entirely or partially shared in different study groups, observing the identical score tracking principle. An AVSEC training course creator should take instructional components developed in one location with one set of tools or platform and be able to use them in another location with a different set of tools or platforms. We focus on two of these requirements:

1. ***Adaptability to content and skills***: Knowledge in AVSEC needs to be easily tailored, updated, or extended towards various study groups, study objectives and learning status. Since threats, regulations or security processes can change dynamically and at any time, an LMS has to provide a set of mechanisms to cope with such situations. Skills should be further developed based on knowledge retrieval and data mining from the learner's performances and their assessments. The profiles of learners and their skills should be balanced and effective course design needs to enable fast and flexible learning. Therefore, learning scenarios need to be highly configurable and scenarios for tests and assessment be easily changeable.

2. ***Collaboration among learners***: Learning is a structured and recursive process by which behavior changes as a result of learning experience, for a recent discussion on learning see for example [14]. By means of sharing knowledge, peer-assessing, and building consensus, all participants, as well as all facilities involved in the same learning scenarios, should concur towards an intellectual endeavor. Also, they should be able

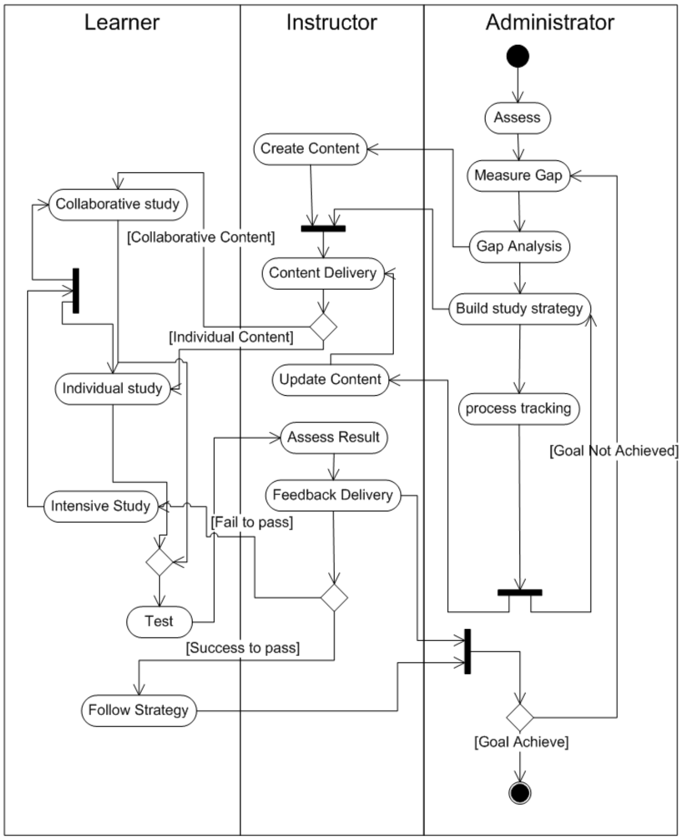

Figure 1. Activities in the AVSEC LMS

to exchange data via different kinds of media. Furthermore, people should be made aware of their performance with respect to the learning goals and the progress of others (in different locations). Therefore, building different learning processes based on various learning subjects and objects is important.

Figure 1 shows the supported LMS activities across different roles of users ranging from learners to instructors and administrators.

2.3 Architectural Components

According to the above given requirements, we propose a six-layer architecture, shown in Figure 2.

1. ***Repository layer:*** The repository layer, composed of knowledge repository and learning process repository, is used to store particular types of knowledge and learning processes.

   For the learning process repository, two different kinds of learning plans are adopted to store implicit and potential learning processes: "heuristic rules" and "case profiles." However, both knowledge and learning processes are implicit in this layer.

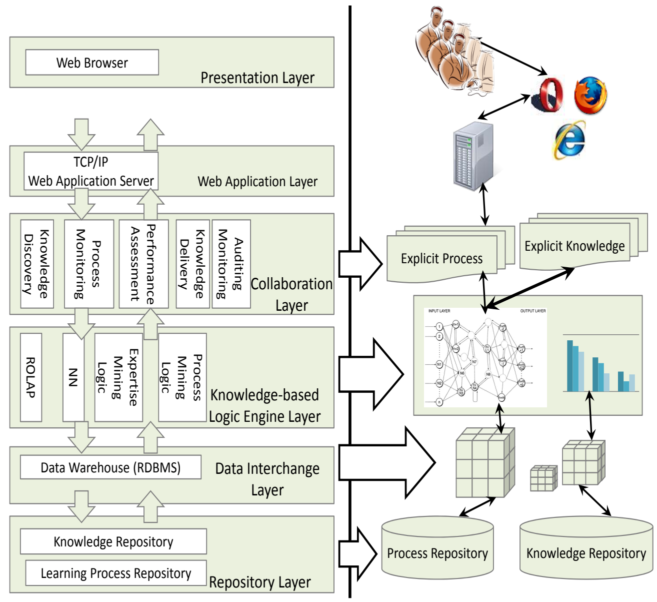

Figure 2. Architecture of AVSEC LMS

2. ***Data Interchange Layer:*** This layer provides a mechanism for processing implicit and unstructured knowledge or learning processes into data structure in the form of OLAP cubes, to be stored in a data warehouse. An OLAP cube represents an arrangement of data in arrays to enable further fast and accurate analysis.

3. ***Knowledge-based Logic Engine Layer***: This layer is one of two core layers of our AVSEC LMS. It accesses data stored in a data warehouse through a data interchange layer and provides OLAP and expertise data mining analysis results by utilizing potentially different data analysis algorithms, such as neural networks (NN), Relational OLAP (ROLAP) and hybrid data mining algorithms.

   Analysis requests coming from the upper layer will be dynamically transformed into SQL execution plans by logic engines. A ROLAP engine [9] supports sophisticated analysis and delivers key performance metrics to evaluate knowledge in user-customizable format. These metrics include multidimensional ratios, comparisons, ranking and statistical profiles.

   Data such as trainee's training time, prerequisite of knowledge and trainee's competencies, are fed into a neural network [8]. It then provides recommendations as explicit knowledge for upper layers. In the case of a learning process, the Process Mining Engine allows the analysis of learning processes to be based on event logs. Event logs, also referred to as status records, are used to record the trainee's states and activities during the learning process. Therefore, they can also be used to compare with some a-priori model [4] to see whether the observed reality conforms to some prescriptive or descriptive model [4]. As a result, explicit learning processes are generated for the Collaboration Layer.

4. ***Collaboration Layer***: This layer accesses the explicit knowledge and learning process data and builds-up status data during the executing learning processes. The Knowledge Discovery component is responsible for providing records for the knowledge itself. Process monitoring and auditing components are concerned with the extraction of knowledge from learning process execution logs. For example, learning resource creators might be interested in recording each of the stages in a particular course element that most learners (e.g. screeners) failed. These could be learning elements, sub-chapters or chapters. Therefore, comprehensive execution logs are generated (as XML files) from various steps. Consequently, both knowledge and learning process execution logs should be delivered to course designers or supervisors for analysis.

3 AVSEC Adaptive Learning

The term *adaptive learning* concerns the high flexibility and scalability of our LMS. Knowledge must be reusable, interoperable and easily organized at many different levels of complexity throughout the on-line instructional environment. Our AVSEC LMS must accommodate various and numerous learner requirements, needs and objectives.

Moreover, the needs of instructors and instructing organizations must also be addressed. Achieving this level of adaptability will require advances in a wide range of technologies that support diverse training tasks. They include a dynamic process engine, information retrieval, data mining and network middleware. Therefore, we propose to add a new extension to the specification of SCORM by utilizing state diagrams from UML 2.0 instead of SCORM-LSTD [12] to describe the states and actions of training participants.

Figure 3 represents one example state diagram of a study group. Each state diagram is transferred into a description file in XML format. Each XML file should be translated into sequencing and navigation and then added to the corresponding content package. Our AVSEC LMS provides a learning process engine which behaves as a state machine while interpreting the sequencing and navigation rules. As soon as a learning state transition is triggered by a trainee's action, a course resource update action will then be executed to match the trainee's state of learning. The assessment action will trigger a global update of trainee learning states. Whether all states of a trainee will be updated is determined by an assessment value and calculated according to either individual self-assessment, auto-assessment and peer-assessment, or a synthesized value. This is configurable to enable adaptive learning.

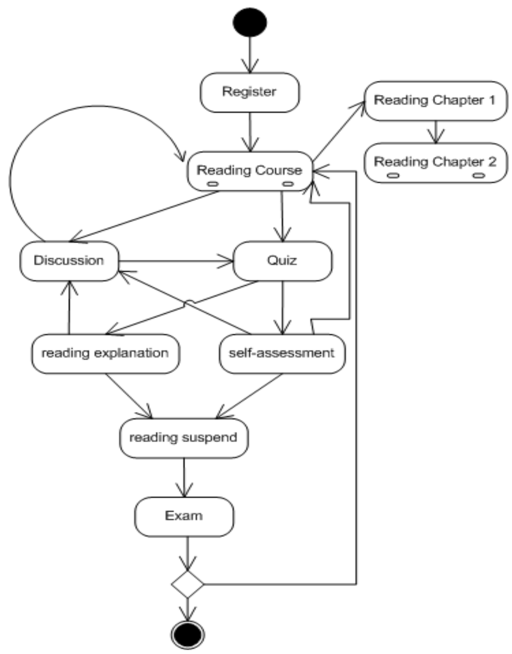

Figure 3. Example of state diagram of a study group

4 AVSEC Collaborative Learning

Several studies have identified the problems caused by a lack of coordination during the learning process, and the extent to which competitive advantage can be gained from a seamless LMS [12]. Therefore, adding a collaboration layer within the LMS is beneficial. For example, a new regulation attached with a video presentation is presented to one group of screeners. After studying this piece of information, they are required to write a report or self-evaluation by themselves. Alternatively, they could discuss the results in groups and each screener could evaluate each other's study achievement peer to peer.

Figure 4 shows an example of collaborative learning by a use case diagram. In the case of some use cases, different trainee groups and instructors need to be involved in the same collaborative study context. Accordingly, an LMS should provide such collaborative facilities. Our architecture addresses the collaboration issues by iterating interactions while connecting a screener to various other parties according to his/her actions. For example, discussion and peer assessment can be performed in trainee groups.

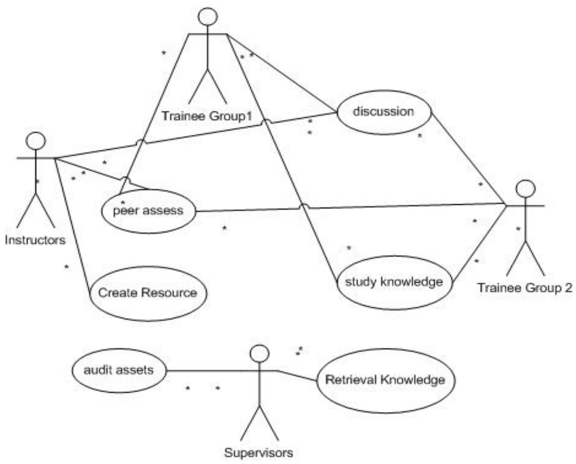

Figure 4. Example of Collaboration Learning Case

In our architecture, we provide some collaborative learning tools in order to support the above use cases. The emergence of Web 2.0 has empowered end users with web-based interactions. Such technologies include Blogs, Instant Messaging Tools, or Wiki systems. Thus, AVSEC LMS architecture integrates such necessary modules based on airport security requirements. It also integrates a set of regulations and constraints, together with corresponding contexts, in order to benefit the end users' actions. Therefore, all interactions between trainees are under the control of supervisors and learning organizers. Regulations and constraints, derived from a certain learning process, are first parsed as XML files and stored in an explicit regulation repository. According to the stored constraints and regulations, trainees are required to utilize associated collaborative tools to discuss, either self-assess or peer-assess, and publish shared information to achieve the learning goal. Each action has to be recorded during run-time.

5 Case Study

In this section we describe a case study of an Aviation Security system and its realization following our adaptive and collaborative knowledge and learning management architecture.

During the implementation of our AVSEC LMS, a course creation and delivery environment was built, whereby LMS instructors can simply create new courses, new chapters within courses, and new course elements within chapters, using and editing a tree hierarchy of a course. A course element may have several learning objects associated with it: for example, a new regulation regarding manual search at checkpoints including a picture and text description, the associated PowerPoint presentation, and a feedback form. There is a facility to edit, move, reorganize, duplicate and delete course elements and add learning objects through a Course Content Management module.

Meanwhile, our AVSEC LMS also provides full conformance to SCORM packages with validation functions. Supervisors play a major role in building learning strategies according to the course content created by instructors. Some elements of a learning strategy will then be transferred into XML files and then automatically added in SCORM content package structure as sequencing and navigation rules. Group study states will be recorded and calculated by means of a knowledge-based analysis engine, reflecting both learning resource and strategy updating. An auditing and monitoring process is also created and stored in process repository. Once the course content is created and compiled for release, a publication mechanism releases the course content to all concerned and integrates it with collaborative functions such as discussion forums and Wiki systems. All concerned LMS users are informed by means of email, SMS or IM tools, given by a link to a corresponding course register form. A flexible role based permissions system is provided to give the multiple permissions required. Simultaneously, supervisors can start an auditing and monitoring process defined at the course creation stage.

From a trainee's perspective, the airport screeners can log in to a particular course and their progression can be monitored. The system automatically configures content and the look and feel of the web environment based on the screeners progression. The AVSEC LMS knowledge-based Engine layer then extracts background knowledge to dynamically deliver relevant information to each screener. Each step of progress or learning action affects it's learning state updating. As soon as the accumulation value reaches a threshold of state updating, the state will be updated followed by new knowledge content delivery being triggered.

6 Status of Prototype

The proposed architecture has been partially implemented in one European airport. The Repository Layer and the Data Interchange Layer have been implemented by PostgresSQL. Some data analysis facilities and knowledge-based algorithms necessary in the knowledge-base layer have been developed within hundreds of stored procedures by means of C, R, as well as PLPGSQL language. The Web application layer and presentation layer have been implemented in .NET 2.0.

The Collaboration layer has been designed to integrate a process-execution engine, various external interaction modules such as a Wiki system and a discussion community. Some modules have already been tested and installed in the real production environment. The Information Board module is one such example that allows a course creator to create learning information and resources by means of *WYSIWYG*. Hundreds of learning elements, referred as "information," have been created and distributed to corresponding trainee groups. The course and test module is in the process of being tested. The auditing and monitoring module is currently being developed.

7 Conclusions and Future Work

In the domain of aviation security we need specific mechanisms to quickly adapt to new learning content, to support different roles ranging from screeners to supervisors, and to enable flexible training scenarios and solid job assessments. This is different to current Learning Management Systems that do not provide this adaptability and collaboration requirements. A learning system has to be flexible and adaptive both in knowledge and in organizational dimensions. In addition to that, collaboration is another requirement that current LMS do not meet: information exchange between different roles across several locations has to be integrated for an effective analysis of training results.

In this paper we presented a six-layer architecture for Aviation Security and discussed some of its application scenarios. Our aim is to improve the quality and usefulness of LMS in AVSEC by utilizing knowledge-based analysis for data analysis and integrating a process engine for collaborative learning. Our first prototype is currently being tested at the customer's site and feedback is very promising.

For future work we foresee to integrate the many screeners' comments and suggestions into the particular components. We will further add all the analytical mechanisms of data analysis to improve the design of the adaptive learning courses.

Acknowledgments

This project is funded by Applied Psychological Science Solutions (APSS). Thanks to Mathias Neukom and Manuel Meyer for their efforts on the AVSEC LMS 0.3 version. Thanks to Franziska Hofer and Diana Hardmeier for their contributions regarding the functional requirements of the LMS. We also thank Zurich State Police, Airport Division for their collaboration in testing the LMS prototype.

References

[1] Click2learn. Available: `www.sumtotalsystems.com`.

[2] Saba. Available: `www.saba.com`.

[3] WebCT. Available : `www.webct.com`.

[4] W. Aalst and C. W. Günther. Finding structure in unstructured processes: The case for process mining. In T. Basten, G. Juhas, and S. Shukla, editors, *Proceedings the 7th International Conference on Applications of Concurrency to System Design (ACSD 2007)*, pages 3–12, Bratislava, Slovak Republic, 2007. IEEE Computer Society Press, Los Alamitos, California.

[5] Advanced Distributed Learning (ADL). Scorm 2004 3rd edition sharable content object reference model, 2004. Available: `www.adlnet.gov/scorm/20043ED/Documentation.aspx`.

[6] O. Bohl, J. Schellhase, R. Senler, and U. Winand. The sharable content object reference model (SCORM) - A critical review. In *ICCE*, pages 950–951, 2002.

[7] P. Clements, F. Bachmann, L. Bass, D. Garlan, J. Ivers, R. Little, R. Nord, and J. Stafford, editors. *Documenting Software Architectures: Views and Beyond*. Addison-Wesley, 2001.

[8] H. Cohen. How useful are current neural network software tools. *Neural Network Review*, 3:102–113, 1989.

[9] G. Collait. OLAP, relational, and multidimensional database systems. *SIGMOD Record*, 25(3):64–69, Sept. 1996.

[10] K. DiMeo, R. Sollenberger, P. Kopardekar, S. Lozito, M.-A. Mackintosh, K. Cardosi, and T. McCloy. Air-ground integration experiment. http://citeseer.ist.psu.edu/dimeo02airground.html, January 2002. a publication of National Technical Information Service, Springfield, Virginia, USA 22161.

[11] B. M. Jenkins and L. N. Gersten. Protecting public surface transportation against terrorism and serious crime: Continuing research on best security practices. http://citeseer.ist.psu.edu/jenkins01protecting.html, September 2001. a publication of the Mineta Transportation Institute, College of Business, San Jos é State University.

[12] Y. Morimoto, M. Ueno, I. Kikukawa, S. Yokoyama, and Y. Miyadera. SALMS: Scorm-compliant adaptive LMS. In G. Richards, editor, *Proceedings of World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education 2007*, pages 7287–7296, Quebec City, Canada, October 2007. AACE.

[13] S. Singh and M. Singh. Explosives detection systems (EDS) for aviation security. *Signal Process.*, 83(1):31–55, 2003.

[14] L. Son and A. Vandierendonck, editors. *Bridging Cognitive Science and Education: Learning, Memory and Metacognition*. Psychology Press, part of the Taylor & Francis Group, 2007.