Real-Time Simulation for Safer Vascular Stenting – The Training Application

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Abstract—We present a novel web-design e-learning platform for vascular surgeons of peripheral arteries. The training application enables experts to prepare educational, training content for their trainees (medical students, endovascular surgeons at their first steps in the specific competence) and the trainees to use real patient data, process the data, go through the whole condition assessment and, finally, take all the important decisions suggested by a training scenario.

I. INTRODUCTION

Peripheral vascular disease (PVD) concerns with the obstruction of arteries other from coronary and brain arteries. The treatment of PVD depends on the severity of the disease and includes management of risk factors such as diabetes, hyperlipidemia and hypertension, drugs, and finally angioplasty, bypass graft and amputation.

The treatment decision is of utmost importance and requires expert knowledge from an experienced doctor, so that significant effort has been devoted to the development of training systems facilitating the successful engagement of young vascular angioplasty surgeons [1-6]. Several commercial systems were deployed such as those provided by Simbionix (Simbionix Ltd, Israel), Therenva (Therenva, Rennes, France) Mentice (Mentice, Gothenburg, Sweden) and CAE Healthcare (CAE Healthcare, Montreal, Canada). These systems offer a realistic environment of the surgery providing training possibilities in real scenarios. Besides commercial systems, web-based training applications have been developed for training vascular surgeons. The Society for Cardiovascular Angiography and Interventions (SCAI) [7], NHS [8], WeBSurg [9] and the Surgical Technologist [10] are the four, most relevant to Real-Time Simulation for Safer vascular Stenting (RT3S) training platform concept (introduced in this work) web-based applications in the literature. The key characteristics of the above mentioned applications are the utilization of slides, images, video, audio and animation of high quality, real life scenarios, case studies, surgical protocols and equipments, and operative techniques.

The RT3S training application is a novel tool for designing, managing and delivering online collaborative learning activities. RT3S training application is e-learning oriented and based-upon the latest e-Learning standards such as IMS Learning Design (IMS LD) [11-12] for the implementation of training scenarios. RT3S training application provides tutors with a highly intuitive visual authoring environment for creating sequences of learning activities of increasing difficulty and can address different user types for different educational objectives. Learning activities range from individual tasks and small group work, to class activities. Furthermore, it offers tutors a customizable distance learning solution for training or examining their students at any time and any place. The RT3S training application is available on the Web at [13].

The proposed training platform incorporates all the characteristics of existing applications [7-10]. However, it goes one step forward and realizes a learning experience in a sequence of steps allowing (at each step) interaction with system modules for viewing patient related information, question/answering interaction e.g., for justifying decisions on the management and treatment of patients (diagnosis, additional examinations needed, drugs for managing other diseases the patient may suffer from etc.). More specifically, in relation to the vascular stenting application under consideration, it allows suggesting endovascular materials needed (e.g., stents), permits interactive positioning of a stent on patient's images and the prediction of the fatigue fracture risk.

Overall, the training application suggests a learning environment demonstrating possible solutions as well as their implications in patient's life in the case of wrong treatment decision. In addition, the content of the training application can be easily adapted to the learning objectives and can include engineering simulation for stent design and cardiovascular devices. Also, the training application can integrate engineering simulation results, such as models of arteries, strain and stress results, definition of a fatigue test, helping users to understand concepts such us modeling and simulation as well as, their utility and significance.

In the next sections the user groups, the functionalities, the architecture as well as the evaluation results of the training application are presented.

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II. METHODS

A. User groups

The user groups of the training application are the experts in vascular medicine, the trainees, the medical students and the qualified vascular surgeons. The application enables the experts to prepare educational, training content for their trainees and train them in decision making. The trainees complete the scenarios assigned by the experts, become more familiar with various cases and prepare themselves for making decisions for their patients. The medical students, following simple scenarios, can improve their knowledge on the specific medical domain and they can decide if the endovascular interventionalist competence is what they want to develop in their career. Finally, the training application offers to the qualified vascular surgeons, through the inclusion of some rare and difficult patient cases, the possibility to enrich their knowledge in the framework of continuing education.

B. Functionalities of the Training Application

The proposed training application consists of two basic environments, the tutor's environment and the learner's environment (Fig. 1). The tutor's environment is the place where the tutor can design a new learning sequence, modify the existing sequences, select a sequence from the sequence repository, assign a group of learners, activate the sequence for learners and monitor their progress. More specifically, the functionalities that are provided to the tutor are the following:

a) Design the scenario: the design of the sequence depends on the learning objectives of the tutor. He decides what the trainees should learn through the scenario and if the approach is in agreement with their background and experience. Then, the tutor selects the learning activities that best serve a learning design. The training application offers the tutor a variety of tools to facilitating the design a learning sequence and for strengthening a learning experience such as, noticeboard, assessment of decisions taken or of answers provided during a question / answering interaction. The repertoire of tools to choose from include also notebook, voting, chat, image gallery, file storage, survey, sharing of resources and Wiki tool.

b) Select trainees that can work with the scenario: To accommodate the needs of trainees with different background or learning behavior, the application allows the tutor to personalize the training process to the background and the experience of the learner.

c) Add and modify learning scenario content: The tutor can craft new scenarios or edit existing ones in short time for importing updates, correcting errors or adapting them to the needs of learners (e.g., a new class).

d) Export/Import Scenarios following the IMS Learning Design (LD) standard [11]: The tutor can export the structure of the scenario and create an XML document describing the content of the activities that are involved. Importing a document in IMS LD format involves the inverse sequence of activities. Also, the tutors can export what has been seen by the trainees using a portfolio export function, creating a record of the lesson.

e) Observe training activity: This functionality includes monitoring of the execution of a scenario or of trainees who have started a learning sequence

The learner's environment is the place where the learning content created by the tutors is presented to the trainees. The trainee can only select the scenario and then follow the sequence of steps depicted in the scenario. During the scenario the trainee can have the possibility to view patient related information, to answer some questions, justify on decisions on the management and treatment of patients.

The training application, besides tutors and trainees, supports functionality for system management by administrator users who are responsible for setting up and maintaining the desired training functionality, user management, for operating the training system and its operation on the Web.
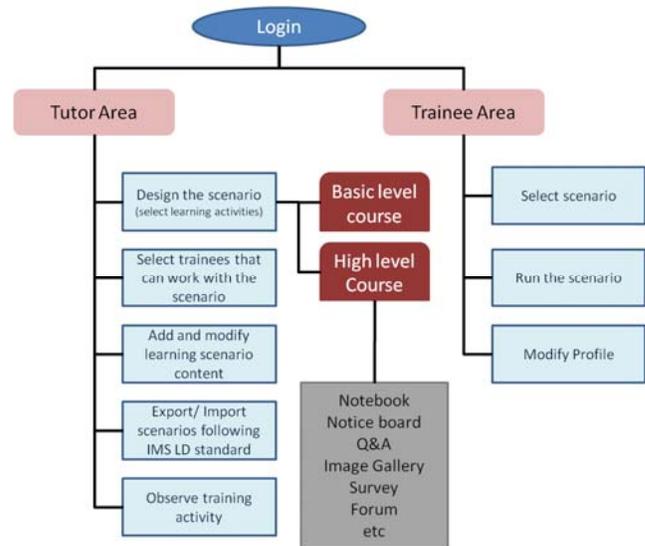

Figure 1. Functionality for the main users.

C. Training Application Architecture

The RT3S training application implements a modular architecture (Fig. 2) where tools and learning activities can be added on-the-fly to a Learning Activity Management System (LAMS) server [14]. LAMS architecture consists of two main components: the Core and the Activity tools. The Core has modules for authoring, administration and learner/trainee roles. The Core manages the elements that form the structure of the scenario, the order of the activities, allocating users to groups, managing when users can progress to particular activities, takes care of logins, system administration, etc. The Activity Tools component includes self-contained modules, which form most of the visual functionality of the content the learner interacts with in the RT3S training application. Activity tools are used in order to allow tutors to present information in the form of text, images, links, flash files and any other HTML features, to create a series of questions, to add content into a sequence, to run a synchronous chat or forum over the course of a lesson etc.

The RT3S training application uses the following third party subsystems: Apache Web server [15], JBOSS 4.0.2 application server [16], Java Sun JDK 6 [17] and MySQL 5.5 or 5.1 database server [18].
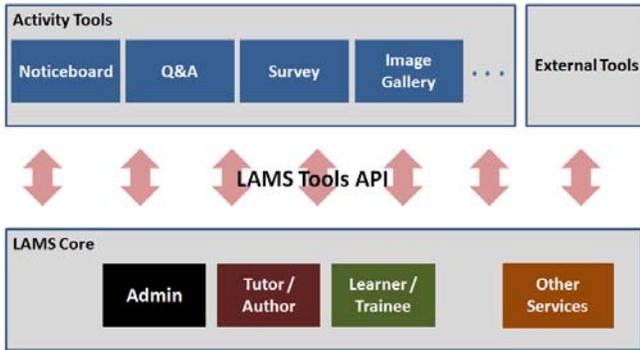

Figure 2. Architecture of the training application as [14].

D. IMS Learning Design standard

The training application is inspired by the e-Learning paradigm and is realized as a Learning Content Management System (LCMS), supporting: data creation, storage, retrieval, reuse, delivery of content (data and scenarios). As already mentioned above, the RT3S training application relies on IMS LD standard [11] for the implementation of training scenarios. This is a main design decision and a characteristic that differentiates the proposed training application from existing ones [7-10]. IMS Learning Design (IMS LD) provides a containment framework of elements that can describe any design of a teaching-learning process in a formal way. IMS LD consists of three levels. Level 1 includes the core elements of the meta-language and the vocabulary for describing people, activities, resources and their interaction. Level 2 allows definition of properties and conditions over elements of the previous level (e.g., introduces greater flexibility by allowing personalization and more elaborate sequencing such as branching (i.e., decision making) in a learning scenario. For example, the user is allowed to follow different path-ways depending on the decision he/she is taking at a stage of a learning sequence. Level 3 includes more sophisticated learning designs such as notifications, messaging after learner's response, etc.

Compliance with the IMS LD standard allows educational content developers to model who does what and with which content in order to achieve learning objectives. It also allows processes to be designed to include several roles, each of which can be played by several people and it enables their activities to be specified as "learning flows" or "learning sequences" that are analogous to workflows.

III. RESULTS

To show proof of concept, realistic scenarios (i.e., based on a real patient case) have been developed demonstrating basic pre-operation steps (before an angioplasty operation takes place) that are routinely followed once a patient has been accepted into the hospital. Eleven evaluators, representing different ages, sexes, and experience with relevant applications, were selected for the evaluation of the application using the scenarios. They were provided with a short description of the application, and then they were allowed to use it for almost an hour.

The users completed an evaluation questionnaire about functionality, aesthetics, ergonomics, and completeness. Each evaluator was asked to rate his answer on a scale 1 through 5, with 5 being the highest score. Some "yes-no" questions were also included and, in some cases, the evaluators were also able to add comments. Table I illustrates an overview of the evaluation results.

TABLE I.   AN OVERVIEW OF THE EVALUATION

Evaluation Overview	
Intuitiveness of the application and easiness to navigate throughout	3.36
Look and feel of the application	2.45
Approval of the scenario based approach	4.27
Clearness of the various scenario steps	3.09
Adequacy of the provided data	3.09
Presentation of the data	3.36
Ability to see other students' answers	3.27
Achievement of the educational objectives	3.09
Potential of the final application to train the learner	3.36
Appropriateness of the tool to train the learner in decision making	3.18
Application to be part of the training for gaining clinical competence	3.36

In general the results were encouraging. For the majority of aspects evaluated, the overall mark for the evaluation was between 3 and 5. This is considered to be an adequate outcome taking into consideration that this is the first version of the training system. The scenario-based approach was rated highly with an average score of 4.27 indicating that the application is moving in the correct direction. On the other hand, the low scores obtained for the "look and feel" of the application (2.45 - just below half) emphasizes that there is significant room for improvement in this aspect. This is considered reasonable for the first version.

An example scenario consists of the following stages: In the first stage of the scenario, the Learning Objectives are defined in order to trigger the learner and convince him about the profit he will have from this learning activity. Then, the data from the patient's health record are available for the trainee to view allowing him to make an initial assessment (introducing the patient). The data are organized in tablets each one containing groups of information such as historical data, medication, laboratory tests and diagnostic imaging. The third stage is the Case assessment where the trainee is asked to record his initial diagnosis for the patient and the relevant justification. A user can then also see what other users have answered as well as what the expert's feedback is.

The diagnostic imaging examination (pre-intervention) is available in the fourth stage of the training through an image gallery with the most important diagnostic frames and a video of the whole imaging sequence (Fig. 3). In the Treatments decision stage (fifth stage), the trainee is asked to make decisions and justify them and then he receives the experts' consultation with the detailed explanation supporting these decisions (Fig. 4). In the sixth stage, the trainee is asked to select the materials and devices (sheaths, catheters, stents, balloons) needed for the treatment of the specific case (endovascular materials) (Fig. 5). The scope of the activity is to encourage the learner to become more familiar with endovascular materials/devices. In the Angioplasty report stage (final stage) a summary of the actual intervention is available for the trainee. Through that report he can see the patient pathway step by step, and how the treatment was performed.

IV. CONCLUSIONS

The RT3S training application is a web-based training apporach inspired by the e-Learning paradigm. It is realized using state-of-art technologies and stanards such as Learning Design (LD) and LAMS (for the implementation of the training process), Java and Flash (for the system and user interface respectively). The application, in its current form, is geared towards the needs of trainees gaining their endovascular clinical competence. It is expandable and ready to accommodate future needs of its users.

The courses are real-life scenarios that endovascular surgeons confront in their daily clinical practice and supports trainees in improving their skills in vascular medicine. Including new (more involved) scenario (e.g., scenarios involving decision making and branching during a learning sequence), improving the look and feel of the user interface and implementaton of additional functonalities for tutors are important issues for future work.
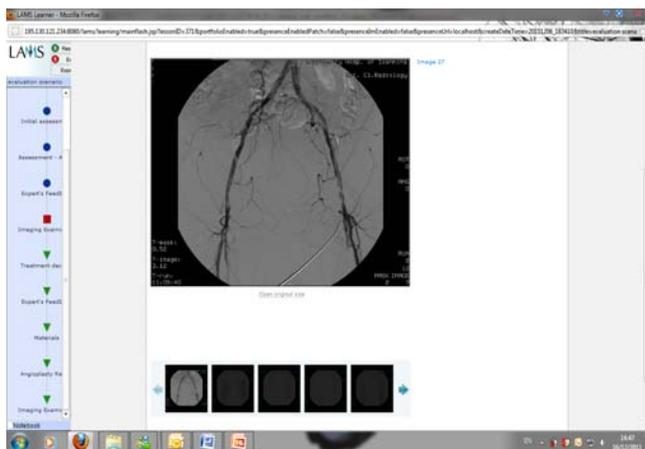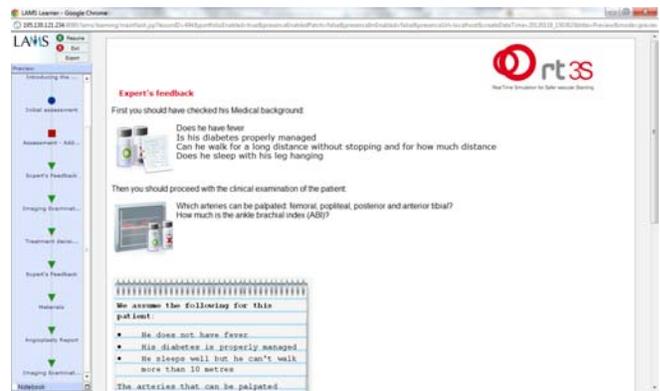

Figure 3. Imaging sequence stage.

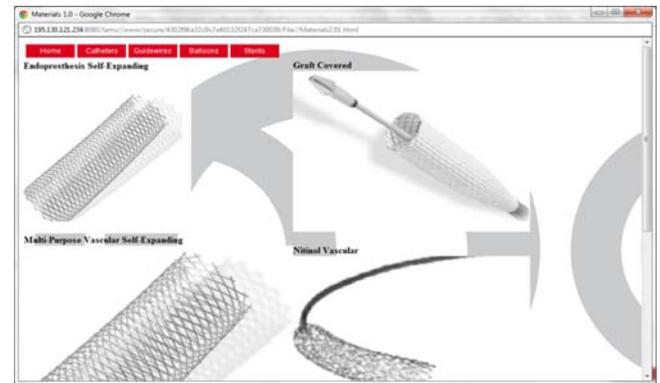Figure 4. Expert's feedback on the assessment of the patient.

Figure 5. Endovascular materials – Stents.

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