Facilitating student understanding of Internetworking via e-learning

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Abstract

Learning Management Systems (LMSs) are widely used in higher education to improve the learning, teaching, and administrative tasks for both students and instructors. Such systems enrich the educational experience by integrating a wide range of services such as on-demand course material and training, thus empowering students to achieve their learning outcomes at their own pace.

Courses in fields of Computer Science that provide rich electronic learning (e-learning) experience depend on exercise material being offered in the forms of quizzes, programming exercises, laboratories, simulations etc. Providing hands on experience in courses such as Internetworking could be facilitated by providing laboratory exercises based on virtual machine environments where the student studies the performance of different internet protocols under different conditions (such as different throughput bounds, error rates, and patterns of changes). ~~The~~ integration of such exercises and their tailored virtual environments is not yet very popular in LMSs.

This thesis project investigates the generation of on-demand virtual exercise environments using cloud infrastructures and integration with an LMS to provide a rich e-learning in an Internetworking course.

- e-learning, lms, capabilites
- Importance of hands on training, lack of online exercises for internetworking
- briefly mention the goals / outcome of the thesis

Acknowledgements

I would like to acknowledge ...

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List of Acronyms and Abbreviations

e-learning electronic learning

LMS Learning Management System

LTI Learning Tools Interoperability

LIS Learning Information Services

EC2 Elastic Compute Cloud

IT Information Technology

AWS Amazon Web Services

KTH Kungliga Tekniska Högskolan

TC Tool Consumer

TP Tool Provider

GLUE! Group Learning Uniform Environment

SCROM Sharable Content Object Reference Model

Chapter 1

Introduction

The use of electronic learning (e-learning) technologies has been well established in modern education to assist both students and instructors in their learning, teaching, and administrative tasks. One of the ~~most widely adopted~~ e-learning technologies by the academic community is Learning Management Systems (LMSs). A LMS is a software application that handles all aspects of the learning process [1], enabling instructors to design rich e-learning courses and students to experience self-paced learning using a variety of features such as on-demand course material, video lectures, automatic delivery and evaluation of assignments, collaboration tools, etc.

Many courses, especially in fields of Computer Science depend on training events in the form of programming assignments, laboratory exercises, simulations, etc. The activities are crucial for students to gain hands-on experience with complex concepts and systems [2]. Although LMSs support on-line training events such as interactive quizzes with automatic evaluation and analysis of results, providing training events that depend on using complex virtual environments and software are not yet very popular.

One of the main advantages of using LMS is that ~~they~~ can support the integration of external applications to provide personalized, domain specific e-learning, such as messaging and video streaming services, on-line office suites, collaboration tools, or even training environments with exercises tailored to the needs of specific courses.

1.1 Background

Hands-on experience is very important to achieve understanding of complex systems and concepts. For example, when studying computer networks, laboratory exercises are a common student ~~practice~~. An Internetworking course often involves students studying the performance of different Internet protocols under different conditions (such as varying throughput bounds, error rates, and patterns of changes).

These experiments depend on specific software, network topologies, and local or virtual hardware. Traditional approaches for realizing such environments depend upon the student's own hardware or on-site computer labs with pre-configured software[3]. More modern approaches involve remote access to virtual machines running on central servers or cloud infrastructures [4].

LMSs do not have built-in support for such laboratory environments. ~~O~~ne of the main advantages of designing an on-line course on top of an LMS that supports the integration of extenal applications is to provide tailored functionality for the course's and student's specific needs. Instructure Inc.'s Canvas [5] LMS implements~~-~~ the IMS Global Learning Consortium Tools Interoperability~~-~~(LTI ®) specification~~ which~~ allows the exchange of information between the LMS and third party components ~~and~~ expose~~s~~ internal functionality of the ~~system~~ to external applications.

Supporting virtual laboratory environments in a LMS ~~for~~ the needs of an Internetworking course, requires the design of a software framework that implements the interoperability specification to exchange relevant information between the laboratory environment and the LMS.

1.2 Problem definition

Hands on experience is very important aspect of the learning process in several fields of Computer Science, including computer networks. Understanding the domain specific concepts and problems of an Internetworking course, depends greatly on exercise material and laboratory practice. ~~Such~~ exercises, are not usually designed to extract suitable analytics for the instructor (as an instructor ~~usually~~ wishes to evaluate each student's level of understanding of different concepts). Assessing the student's understanding is currently achieved via using additional training material, such as quizzes or assignments in forms of reports which are manually evaluated by instructors or by other students in the form of peer reviewing.

Supporting an on-line version of ~~this particular~~ course through a LMS that enables students to achieve the learning outcomes at their own pace, depends greatly on designing interactive practic~~ing~~ environments. Such environments should be easily modified by the instructor to fit the needs of different exercises~~, and~~ provide feedback for both students and teachers. Although LMSs support a variety of training events such as quizzes and assignments through integration of external services, the support for on-line virtual laboratory environments ~~for~~ the needs of an Internetworking course is not yet ~~popular~~.

This project aims to design a software framework that supports interactive training material that extracts suitable analytics of the learning process for both students and instructors, and integrates with a LMS to provide a rich e-learning experience.

1.3 Goals

informal

The design of such a laboratory environment for an Internetworking course has to meet several user requirements from the perspective of both students and instructors, and integrate with a LMS to offer a rich e-learning experience. The expected outcome of this project is a software framework that supports instantiation of on-demand laboratory environments using cloud based technologies to enrich the learning experience of students ~~and~~ allow them to proceed at their own pace. Additionally, the framework should enable a teacher to customize the environment according to different exercises' requirements, and provide ~~him~~ with constructive feedback ~~of the~~ students~~'~~ progress and understanding.

The process of designing this framework can be realized ~~into~~ achieving the following goals:

- Easily build virtual laboratory environments,
- On demand availability of these environments should enable students to practice whenever they want, i.e, be self-paced,
- The framework should support evaluation and analysis methods to be applied to the exercise in a way that is useful for both instructors and students.
- Integration of the framework with the LMS should enable students to access the training environments via the LMS, and
- The method of integration of such exercise environments should be usable by others - thus an important part of this thesis project is documenting the selected method to facilitate the integration of a diverse set of external environments (for example, an ns-3 simulator configured for a particular simulation).

1.4 Research Methodology

Design science research addresses important unsolved problems in unique or innovative ways or solved problems in more effective or efficient ways. It focuses on the design and construction of Information Technology (IT) artifacts that have utility in real-world, application environments. The designed artifacts, as the outcome of the research process, aim ~~in~~ improv~~ing~~ domain-specific systems and processes [6, 7]. The utility, quality and adequacy of a design artifact, is thoroughly evaluated under varying experimental setups to verify ~~the~~ successful fulfill~~ment of~~ the requirements.

Designing, in several research fields, including IT, is an iterative process of planning, generating alternatives, and selecting a satisfactory outcome. Design science research, although it is not performed using strictly defined processes, ~~it~~ can be summarized by three closely related cycles of activities [8], that act as guidelines for designing, constructing and evaluating an artifact. The relevance cycle establishes the application context that not only provides the requirements for the research as inputs but also defines acceptance criteria for the evaluation of the research results. The rigor cycle provides past knowledge to the research project to ensure its innovation. It is contingent on the researchers to thoroughly research and reference the knowledge base in order to guarantee that the designs produced are research contributions and not routine designs based upon the application of well-known processes. The central Design Cycle iterates between the core activities of building and evaluating the design artifacts and processes of the research [6], until the acceptance criteria, as defined in the Relevance Cycle, are met.

This project is carried out using the design science research approach. ~~It is trying~~ to solve the problem of designing a rich on-line laboratory environments for an Internetworking, e-learning course that can be hosted by a specific learning management system (Canvas LMS). The two different domains that define the context of this problem are the computer networks course domain, and the LMS along with the integration of external applications into Canvas.

1.5 Deliminations

informal

This project addresses the problem of designing and integrating virtual laboratory environments ~~for an~~ e-learning Internetworking course ~~into a LMS~~. The laboratory framework, ~~as an~~ outcome of this project has to fulfill several requirements ~~such as~~ usability for different types of users (instructor, administrator and student), integration into the Canvas LMS via the LTI specification, and~~, also~~ satisfy the laboratory and pedagogical challenges of this particular course. Although there are different specifications for integrating external applications and services into a LMS [9], this project addresses only the Learning Tools Interoperability (LTI) specifications, ~~that~~ is supported by Canvas. [illegible]e design of the laboratory framework, is designed ~~according to~~ the needs of a ~~regular size~~ classroom, thus ~~limiting~~ its~~’~~ scalability.

Scalability of the designed system regarding number of users is out of scope. ~~Most probably we will design a~~ system ~~that can~~ be scaled up on Amazon Web Services (AWS) by using larger instances (vertical scaling) ~~and having enough~~ instances ~~available for students to practice~~ (horizontal scaling)~~, but since these types of scaling cost money and they will not be investigated~~. Additionally, ~~the~~ scaling up and down of services in clouds has been invested by others, see for example: http://urn.kb.se/resolve?urn=urn:nbn:se:kth:diva-142361

1.6 Structure of the thesis

Chapter 2

Background

2.1 LMS

LMSs are software applications that automate the training, teaching and administrative tasks of the learning process [1]. They have been widely adopted by higher education institutions to automate their organizational functions and provide a rich e-learning experience for both instructors and students.

Such systems are designed to provide self-guided services, rapid delivery and composition of learning material; tracking and reporting of progress through training programs, classroom or on-line events; personalized content; and centralization and automation of administration [10]. From a learner's perspective the most common use cases of a LMS are planning ones own learning experience and collaboration with colleagues; while from an instructor's perspective the most common use cases are the design and delivery of educational content along with tracking and analysis of students' learning evolution [11].

The main functionality of a LMS concerns content organization and delivery, communication and collaboration, and assessment[1] of student's learning process. Some of the most commonly used features for e-learning are video streaming of lectures, on-line notes and presentations, quizzes and practic~~ing~~ environments, automatic evaluation of assignments (usually exercises with predefined input and output), wikis, discussion forums, etc. [13]

The services mentioned ~~above~~ are either offered directly by the LMS or by integrating external applications that are designed according to specific interoperability standards. Section 2.2 describes interoperability and integration in detail.

There are several LMSs in the market that are used by ~~different~~ institutions. In

[1]

Formative assessment is performed by teachers during the learning process, to modify and improve the teaching and learning activities. It is based on observation of students' individual efforts and development; thus, having a qualitative and diagnostic nature.

Summative assessment ~~can be~~ performed by both instructors and students, is based on public criteria that aim to measure student's achieving of the course learning outcomes. [12]

the scope of this project the chosen learning management platform is Canvas [5]. This LMS was chosen because the system is open source, supports a well defined interoperability specification, and was selected earlier this year by KTH as their future LMS.

You might take a look at http://www.internet2.edu/products-services/cloud-services-applications/canvas/

Canvas SaaS

2.2 LTI

Interoperability is the ~~cap~~ability to communicate, execute programs or transfer data among functional units in a manner that requires the user to have little or no knowledge of the unique characteristics of those units [14]. Designing an e-learning environment often requires the user of several services that communicate with each other to exchange information in a formal, standardized way.

The IMS Global Learning Consortium Tools Interoperability (LTI ®) specification establishes a standard way of integrating rich learning applications (often remotely hosted and provided through third-party services) with platforms ~~like learning management systems~~, portals, learning object repositories, or other educational environments [15]. The main goal of LTI is to standardize the process of building links between learning tools and the LMS [16]. This section ~~emphasizes~~ on ~~the~~ LTI 1.1 version of the specification ~~which~~ is implemented by Canvas LMS.

There are two major pieces of software involved in LTI. The first is called Tool Consumer (TC) and it refers to the LMS that consumes external tools, and the second, is the Tool Provider (TP) ~~and it~~ provides ~~the~~ external tools for use ~~in~~ the ~~Tool Consumer~~. In the context of this project, ~~a Tool Provider is a~~ laboratory environment and the ~~Tool Consumer is the~~ LMS. Communication between providers and consumers is bidirectional. Figure 2.1 presents an overview of the interaction of the different LTI components and types of users.

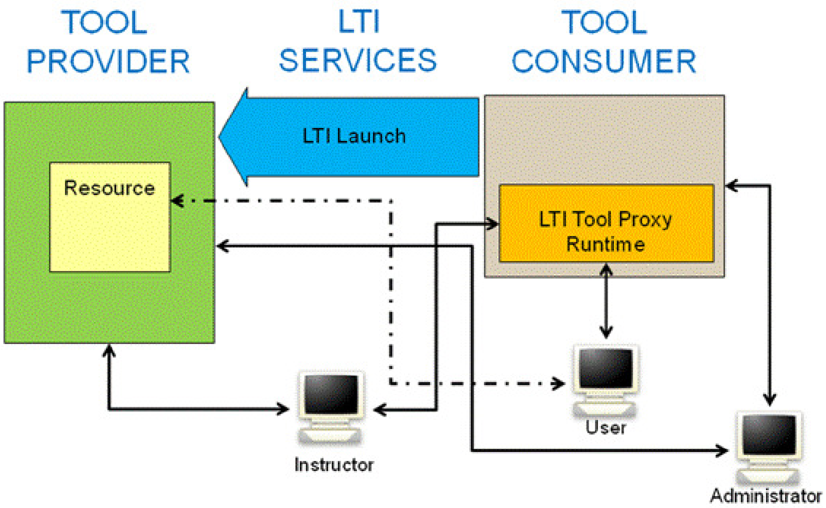

Figure 2.1: Overview of LTI

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A ~~tool provider~~ often requires ~~to~~ access information such as people, groups, memberships, courses and outcomes. ~~Such~~ information along with standardized ways of retrieving it ~~is~~ defined by the IMS Global Learning Consortium Learning Information Services (LIS) specification [17]. These services can be provided either by the TC or by a third party system. Figure 2.2 shows how a TP can communicate with LIS services. In this example the TC performs a LTI launch and provides the TP with information (LIS pointers) ~~on how to~~ acces the LIS services.

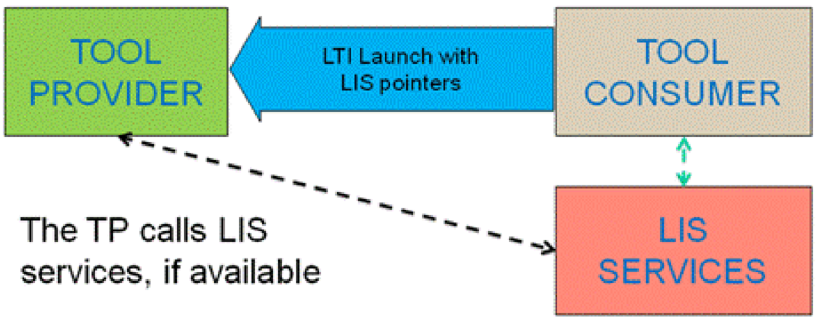

Figure 2.2: A TP using LIS services

Copyrights of figure

2.3 Efforts to provide on-line exercise material

Traditional practic~~ing~~ events in ~~fields of~~ Computer Science involve laboratory environments and exercises based on virtual hardware and domain specific software.

~~Mention~~ the problem ~~of~~ creating and managing those environments. Previously such material was packaged in virtual machines. With the rapid growth of e-learning courses the need for on-line exercise material has grown. Efforts in fields of cybersecurity ~~are~~ ...

Some useful references for exercise material ~~and setup to expand on~~:

- ~~A Comparison of Virtual Lab Solutions for Online Cyber Security Education~~
- Hands-On Experience to a Massive Open Online Course on openHPI
- Some Experiences in Using Virtual Machines for Teaching Computer Networks
- ~~TOP 10 HANDS-ON CYBERSECURITY EXERCISES~~
- V-Lab: A Mobile Virtual Lab for Network Security Studies
- IK1550

More info

- What are the requirements for successfully completing an exercise?

  What information about a student's progress in or success with the exercise should (or could) be communicated back to the LMS?

- How are these requirements met by the chosen technologies?

2.4 Related work

2.4.1 EDURange

Designing on-line training environments for the field of cyber security requires to overcome technical constraints such as high availability and scalability, and pedagogical limitations such as teaching analysis skills to understand complex systems and concepts via practicing [2]. EDURange addresses these issues by designing an open source framework that provides interactive security exercises in an elastic cloud environment [18].

EDURange ~~a~~s a software framework, ~~is~~ designed to work on Amazon Elastic Compute Cloud (EC2) [19]. It allows teachers to easily build and scale dynamic virtual environments to host cybersecurity training [20]. This framework provides ease of use for instructors, by offering flexibility to specify exercises at a high level and allowing the~~m~~ to configure different aspects of the training scenarios in order to provide a tailored learning experience that focuses on analysis skills.

2.4.2 GLUE

Group Learning Uniform Environment (GLUE!) a middle-ware integration architecture that aims to standardize the integration of existing external learning tools into several LMSs [21]. It facilitates the instantiation and enactment of collaborative learning situations within LMSs, by using the distinctive administrative features of these systems ~~such as~~ manage~~ment of~~ users and groups. LTI or Sharable Content Object Reference Model (SCROM) are specifications for the integration of external learning tools into LMS. Each LMS usually supports a single interoperability specifications; thus, developing universal external tool requires a considerable development effort to cover the different standards. GLUE! ~~on the other hand,~~ proposes a software architecture that takes advantage of the common integration features of LMSs to integrate multiple existing learning tools into multiple LMSs.

2.5 Summary

It is nice to bring this chapter to a close with a summary. For example, you might include a table that summarizes the ideas of others and the advantages and disadvantages of each ? so that later you can compare your solution to each of these. This will also help guide you in defining the metrics that you will use for your evaluation.

Chapter 3

Methodology

What scientific or engineering methodology are you going to use and why have you chosen this method. What other methods did you consider and why did you reject them. What are your goals? (What should you be able to do as a result of your solution - which could not be done well before you started?) What you are going to do? How? Why? For example, if you have implemented an artifact what did you do and why? How will your evaluate it.

..

You might explain why Canvas is being used:

- it is likely that this will be the LMS at KTH
- it is open source so you were able to build your own instance and experiment with it.

The rigor cycle provides past knowledge to the research project to ensure its innovation. ~~It is contingent on the~~ researchers ~~to~~ thoroughly research and reference the knowledge base in order to guarantee that the designs produced are research contributions and not routine designs based upon the application of well-known processes. The central Design Cycle iterates between the core activities of building and evaluating the design artifacts and processes of the research [6], until the acceptance criteria, as defined in the Relevance Cycle, are met.

3.1 Research Process

This thesis project is carried out using the Design Science research. This type of research focuses on the design and construction of IT artifacts that have utility in real world, application environments, and aim ~~in~~ improv~~ing~~ domain-specific systems and processes. In the context of this research, the real world problem is the lack of interactive virtual laboratory environments in forms of learning tools~~, that can be~~ integrated with LMSs~~, to assist the~~ learning and teaching ~~functions~~ of an on-line Internetworking course.

Despite the fact that there is no strictly defined process for performing Design Science research, there are three closely related cycles of activities that can be used as guidelines for designing, constructing and evaluating an artifact. The relevance cycle initiates the application context that not only provides the requirements for the research (e.g problem to be addressed) as inputs but also defines acceptance criteria for the evaluation of the research results, thus establishing a bridge between the contextual environment of the research project with the design science activities. It is often useful for defining the application context, to describe the people and the organizational and technical systems involved in the domain of the problem. In the context of this problem, the main inputs are the Internetworking course along with the functional and pedagogical requirements of its laboratory environments, the instructor and student user roles that are involved in designing a learning tool, and finally, Canvas LMS and its support for integrating external learning tools.

These inputs can be expanded to functional and user requirements of the artifact in a section later on.

The rigor cycle of Design Science research provides past knowledge to the project to ensure its innovation. Like traditional literature research, it guides the researcher to identify existing artifacts and processes in the application domain, solutions and design practices to relevant problems, and establishes a knowledge base that ensures the uniqueness and originality of the designed artifact. Here, the rigor cycle is represented by the background literature review, that validates the lack of existing solutions when it comes to domain specific laboratory environments that are offered by LMSs, and presents common practices and design methodologies for constructing and integrating such environments in similar information technology domains like cybersecurity.

Finally the design cycle, is the core of the research method, is tightly bound to the rigor and relevance cycle because of its iterative nature, that generates artifacts according to design specifications and evaluates them against requirements until the acceptance criteria of the research are met.

3.2 Research Paradigm

HTTP traffic widget from FORGE http://ict-forge.eu/wp-content/uploads/2016/01/FORGE-2015-P-D312-Final.pdf

Chapter 4

Implementation

Chapter 5

Analysis

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5.1 Major results

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5.2 Reliability Analysis

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5.3 Validity Analysis

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5.4 Discussion

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Chapter 6

Conclusions and Future Work

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6.1 Conclusions

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6.2 Limitations

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6.3 Future work

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6.4 Reflections

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Appendix A

Appendix Name X

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