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Compilers Lab Revision

An Interactive Qualifying Project Report:

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By:

Alex Ostapenko

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Professor Karen Lemone, Project Advisor

Abstract

A crucial part of the Compilers course, taught by Professor Lemone, is an online laboratory that enables students to acquire hands-on experience with the techniques taught in class. These laboratories are designed to be a concrete foundation that the students will need in order to complete the project component of the class.

This project reviewed and analyzed these laboratory web pages to determine how they can be improved. There are several areas for the types of important improvements that needed to take place, which as a result built upon what is already in place and updated it. This was done to make the laboratories more convenient to use and eliminate potential issues that have been identified both by Professor Lemone and the students that have taken the Compilers course.

Acknowledgements

I would like to thank Professor Lemone for offering me the opportunity to work on this project and giving suggestions and ideas about how to improve upon the existing laboratories. I would also like to thank my student peers for providing additional ideas and feedback for this project.

Contents

Figure Index

Executive Summary

The advancement of the Internet technologies has allowed the phenomenon of distance learning to become a very popular medium for professors all over the world to use. Many educational institutions are now able to provide courses that are taught exclusively online alongside their traditional on-campus counterparts. Even though both approaches have their advantages and disadvantages, the trend for online education is growing, due to the convenience it provides and elimination of physical restrictions such as one's location.

The purpose of this Interactive Qualifying Project was to enhance the online laboratory web pages that serve as a part of the Compilers course, taught by Professor Lemone. This course, in addition to being taught in a traditional classroom environment at Worcester Polytechnic Institute, is also offered as a distance learning opportunity.

In order to achieve the goal of improving the online laboratories, three objectives were developed. The purpose of the first objective was to gather feedback from the students who have completed the labs as part of taking the compilers course. The second objective dealt with analyzing the results from that feedback and applying modifications to the pages. The purpose of the third objective was to create a framework for evaluating the effect of the changes that were made to the laboratory web pages.

1. Introduction

Generally speaking, laboratories are an integral part of most practical and theoretical courses. Their aim is to provide a hands-on experience with the material taught in class. They serve as an effective way to emphasize important techniques and concepts that might be problematic to remember just from lecture notes or reading. For Computer Science courses, such labs are designed to be completed in a fixed environment with a pre-determined outcome. The emergence of online laboratories has facilitated this process and made it more convenient for students, who no longer need to worry about the details of setting up and interacting with the software directly.

An essential part of Techniques of Programming Language Translation, which is taught not only as a traditional course, but also as a distance learning opportunity, is a set of online laboratories developed by Professor Lemone and Todd Cooper. These laboratories are completed by students over the course of the term, both as part of the homework assignments and more importantly as an invaluable help in providing a starting point for the corresponding parts of the term-long project, which is strategically divided into several parts. Because Lex and Yacc - the tools that are used for this course might initially seem confusing for the students, the aim of the labs is to facilitate interaction with them by taking care of the mechanics of executing the software, so that the students can learn the functionality that is provided.

The set of the laboratories consists of four different parts, based on the material that was taught during the lectures and is also presented on the main class site under the "Modules" section. The students are encouraged to apply the theoretical knowledge that

they have gained in order to be able to solve various problems related to how compilers operate. The set of laboratories contains the following items:

1. Scanner Lab – an introductory lexical analysis lab that acquaints the students with Lex and the basic use of regular expressions.
2. Parsing Lab – This one builds upon what was learned in the first lab and adds Yacc to the picture, making grammar parsing possible.
3. Semantics Lab – The third part consists of a Semantics lab, which is used to demonstrate to the students how to create tree structures that store the elements from the parsing into a binary tree and then output them in a form that is easier for people to visualize and comprehend.
4. Code Generation Lab – The final, fourth, part of the labs, combines all the techniques learned in the previous parts in order to create a functional compiler that parses the input strings, creates a parsing tree, and uses an algorithm to output pseudo-assembly instructions that would result in order to execute the program derived from the input source code strings.

Because the laboratories are fully functional, the main task that needed to be completed for this project was the general revision of interactive student experience which includes general execution flow, output of the results, and their general representation. It is an important area due to the fact that this is likely to be the students' first encounter with this kind of software and it is imperative that the instructions and the results that are displayed on the pages are clear enough to be fully understood.

The goal for this project is to enhance the online laboratory web pages for the Compilers course. Three main objectives were developed, whose fulfillment will achieve completion of this goal:

1. Identifying areas that need improvement
2. Updating the laboratories source code
3. Creating framework for evaluating the effect of the changes

2. Background

One of the emerging traits that can be observed in the development of the educational systems throughout the world, is the phenomenon called distance learning. With the recent advances in technology and a high demand from people who cannot follow a traditional class schedule, this kind of learning is an effective means of obtaining a degree, especially considering the fact that most higher education institutions now offer online courses.

2.1 Evolution of Distant Learning

One may argue that distance learning has existed for the last couple of centuries and indeed, there are mentions of this type of education from the early 1800's (Moore, 2005). Of course, when we look back at that particular time, it seems to be a rather primitive approach to education, where students couldn't hear back from the teacher for months at a time. And that is not surprising, considering the fact how fast the technology has evolved since those days. We no longer need to wait for days or even weeks and months in order to receive an ordinary letter, nor does it cost a fortune to call someone abroad. This was all made possible with the emergence and widespread of the Internet. Our communication has become essentially instantaneous, no matter where the communicating parties are physically located on the globe. And what is more important, as a result, people now have a very wide variety of sources and strategies that they can use in order to educate themselves better.

As of today there is a wide variety of different types of distance learning. These can be categorized as follows (Moisseeva, 2007):

- Correspondence via regular mail and email services
- Video and audio communication
- Content found on media such as CDs and DVDs that sometimes accompany books
- Content on the actual e-learning websites

The whole concept on the types of education that are available today in terms of the online component may essentially be viewed as a spectrum, with some courses being taught exclusively online to courses taught in a traditional classroom environment with a moderate degree on reliance on online technology, and finally to courses that are taught in a strictly traditional classroom environment. It was reported that at least 96 percent of higher education institutions in the United States have offered online courses in 2006 (Sloan, 2006). It was also reported that as of 2005, around three million students participated in such an online course (Sloan, 2006):

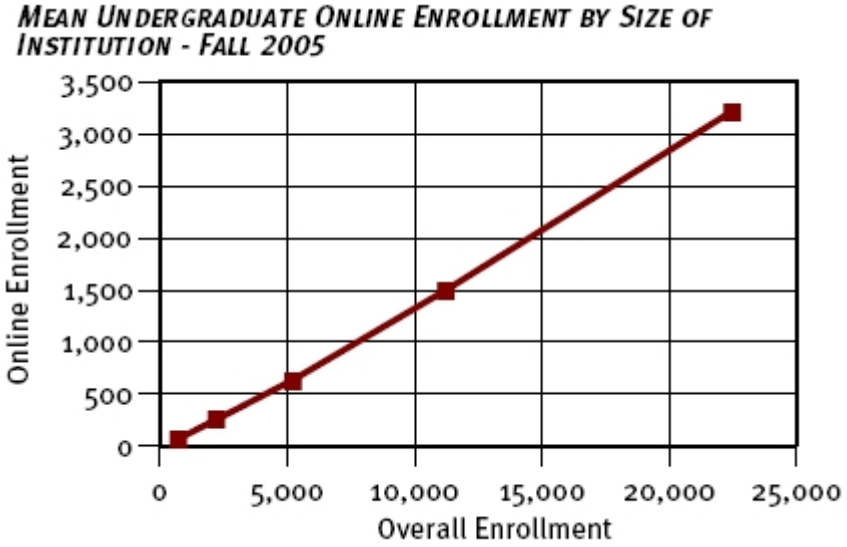

Figure 1 - http://www.sloan-c.org/images/survey_online_size.jpg

Of particular interest to this project is the online laboratory component that some of these courses offer. One of the examples of such a course is CS4533, a Compilers course taught by Professor Lemone, which falls under the category of distance learning (or e-learning) courses.

2.2 Technology behind Distant Learning

As was briefly mentioned above, the people advocating and providing online education have taken advantage of the technologies that were available at any particular time period. It does not come as a surprise that most important of these technologies today are Internet-related (Distant Learning Wisconsin, 2006). This is because the Internet has become as a de facto medium for producing and providing various types of information. The main benefit that this gives the end-users is the fact that in most cases they no longer need to have access to sophisticated instruments, high-end computers and the like in order to advance their education. Usually the educators take care of the back-end functionality themselves, which means that the students require nothing more than a computer with Internet connectivity and a web browser, which is, as the figure below shows, no longer a commodity that is available exclusively to the wealthy portion of the population (Internet Usage World Stats, 2008).

Table 1 - Internet usage in North America

http://www.internetworldstats.com/stats14.htm

NORTH AMERICA INTERNET USERS AND POPULATION STATISTICS						
NORTH AMERICA REGION	Population (2008 Est.)	% Pop. of World	Internet Users, Latest Data	Penetration (% Population)	Usage % of World	Use Growth (2000-2008)
North America	337,167,248	5.1 %	248,241,969	73.6 %	17.0 %	129.6 %
Rest of the World	6,338,953,040	94.9 %	1,215,390,392	19.2 %	83.0 %	380.6 %
WORLD TOTAL	6,676,120,288	100.0 %	1,463,632,361	21.9 %	100.0 %	305.5 %

NOTES: (1) Statistics for North America were updated for June 30, 2008. (2) Population is based on data contained in the US Census Bureau. (3) The most recent usage data comes mainly from figures published by Nielsen//NetRatings , ITU , Computer Industry Almanac, and trustworthy local sources. (4) Data on this site may be cited, giving due credit and establishing an active link back to Internet World Stats . (5) For definitions and help, see the site surfing guide. Copyright © 2008, Miniwatts Marketing Group. All rights reserved.

The figure above shows that the number of people who have access to the Internet is constantly growing, with the United States taking the first place in the percentage of the populace that has access to it.

2.3 Advantages

The main advantages of participating in an online course or a course with an online component are summarized below:

- The convenience that is provided by the online access. No longer do people need to live close to the area where an educational institution is located, because with the global scope of the Internet, it is possible to take a class from virtually anywhere on the planet.

- Higher flexibility. There usually is no requirement to attend a class at a particular time or schedule, because all the studying is done on an individual basis (Distance Learning Net, 2009).

- Simplified setup. As was already mentioned earlier, the students do not generally require direct access to sometimes very expensive technology, which is facilitated nowadays even more with the existence of various kinds of simulators that can be used to contribute to a more hands-on approach to learning.

2.4 Disadvantages

As is usually the case, where there are advantages, there are also disadvantages. Online learning is obviously not for everyone. For some people it takes an extra effort to finish assignments on time and there are also individuals who fall into the group of people who learn more efficiently under direct supervision of a professor. Also as a downside of the lack of direct communication is the fact that some students might abuse the system and cheat and this is sometimes quite hard to determine. Another minor disadvantage of online classes is the fact that the students will be lacking social interaction that is present in the more traditional forms of education (Distance Learning Net, 2009).

2.5 Importance of Balance

Since the main purpose of providing different types of educational approaches is to maximize the effectiveness of teaching, it comes as no surprise that there is no definitive answer which approach is better, because the student's personality and situation in life are the main factors that determine which approach is the best. However, generally speaking, combining traditional methods of education with the more modern online ones will be beneficial to the majority of the students, because they will be exposed to these different approaches, which in the end will help to balance their strengths and weaknesses (White, 2007). This approach is quite common in the classes

that are taught at Worcester Polytechnic Institute. Virtually all of the courses have a website that is designed to provide students with helpful information, such as the syllabus, schedule, homework assignments etc.

2.6 Closer Look at Compilers Laboratories

The indispensable part of the Techniques of Programming Languages is the online compiler laboratories. The course also consists of the main site with all the course-related information such as homework due dates and the tentative schedule for the course. The site also contains several sections that are called modules. Each of these modules is a subtopic that provides lecture notes and various articles that explore the mechanics of compiler technology. These modules also serve as logical parts that divide the term-long project. As a mandatory component for completing the course, each of these project parts also has an online laboratory associated with it. The online laboratories are designed to provide the students with guidance and introduce the compiler-related concepts that are fully explored during the completion of the project. Because they are meant to be presented as introductory material, it is essential that these laboratories are as clear as possible, which applies both to the provided lab instructions, means to complete the required tasks, and the visual presentation of the results to the students. Theoretically, the laboratory tasks can be completed by anyone with enough knowledge to setup the appropriate programs on a Linux machine, but it would require a lot of steps, which are non-essential to the concepts being taught. Due to the fact that the laboratories provide all the required functionality behind the scenes, the users don't need to concern themselves with setting up the execution environment, but instead focus all of their efforts on actually learning the compiler techniques that are being presented.

This set of laboratories is actually a good example of the most important advantages offered by distant learning. The main server where the laboratories are stored is equipped with all the software that is needed in order to provide the functionality that is required from the labs. All the students need is a computer with an Internet connection and a web browser, without having to worry about setting anything up. The way it works is that the students follow the directions provided on the laboratory web pages, submit their modifications via forms present on those pages to the server, which takes these modifications as parameters and passes them to the command line interface. When the execution is completed, the results are displayed back to the users, where they can check them on the same page.

What is interesting to note, is the fact that even though online teaching is becoming so widespread, there are still no common toolkits that might help a professor to set up an online laboratory, even though course management packages such as Blackboard have existed for quite some time. Of course there are various services that offer creation of simple online web sites, but all these sites are capable of doing is displaying instructions to the laboratories, and all the more specialized functionality such as what was described above where the clients are utilizing the software installed on the server, has to be implemented on a case-by-case basis.

3. Methodology

In order to fulfill the goal of this Interactive Qualifying Project, which is to enhance the online laboratories that Professor Lemone uses as a part of her Compilers course, three major objectives were identified. The first of these objectives was to identify the areas that need improvement to provide better user experience for the students who take the course, the second was to update the laboratory source code, and the third was to create a framework for evaluating the changes that were implemented.

3.1 Identifying Areas That Need Improvement

Having completed the Compilers course, I had direct experience with how the laboratories operate. However, more than one opinion is required in order to make changes that will satisfy future students, who usually come from very diverse backgrounds, especially considering the fact that this course is also taught by Professor Lemone as a distance learning course. To obtain other students' opinions, it was decided that the best approach would be to create a paper-based qualitative survey that was distributed to students on the last day of class.

Because existing laboratories are fully functional, further improvement requires direct feedback from the students. Since the user experience cannot be directly measured, the best way to identify areas of improvement is to conduct a qualitative survey.

3.1.1 The Survey

Based on the rationale above, it was decided to create a survey that would allow students who took CS4533 during C term of 2009 to provide feedback about their experience working with and completing the labs. This way, the survey would be a method to fulfill the objective of identifying areas of improvement in user experience. Being a qualitative survey, it would allow gathering feedback from the students about what they liked about the labs, what they thought could be improved, and if they have encountered any technical problems while completing them.

The survey that was given during the last day of class contained four questions. It was decided that in order to get more meaningful answers, the questions should call for an open-ended response, rather than having several fixed-scope True/False questions, which would expand the coverage area of information about various aspects of working with and completing the labs. These questions are reproduced below, with the reasoning about why they were chosen.

Question 1:

Was there something in particular that didn't work for you while completing the labs (please mention if it only applied to a particular lab)?

This question was designed to gather data on how well the laboratories worked from a technical point of view, to find out if there were any particular problems that the students encountered. The answers to this question would also influence the decision of whether any back-end functionality needs to be fixed or modified.

Question 2:

Were there any specific issues that you have faced from the basic usability/interface point of view?

This question was meant to provide information about the actual interactive user experience with web pages that the students accessed in order to complete the labs. This information was the most important input required to fulfill the goal of this project, since the answers would directly highlight the areas of further improvement.

Question 3:

What did you like most about the labs? Were they a useful tool for completing the various parts of the project? If not, state why.

The purpose of this question was to identify what features and functionality most useful and evaluate if there are any gaps and potential for further improvement. This information was needed to prevent possible modifications to the areas that students liked and found useful.

Question 4:

Do you have any suggestions on what could be done to improve the format of the labs?

The last question was essentially used to gather as many suggestions as possible to discover common themes and future venues to improve the laboratory web pages.

3.2 Updating the Laboratories Source Code

The second objective relies on the information that was gathered as part of the first objective. In order to enhance the online laboratory web pages, the results from the survey were evaluated in terms of how much the proposed changes would actually contribute to the goal of the project. This evaluation was made while keeping in mind the guidelines that the optimal online laboratory should follow, such as if the code changes would in some way impose limits on what kind of browsers can be used in order to successfully complete the labs and if they would actually improve the experience in the way the pages are presented to the students. This objective was completed by actually modifying the source code of the laboratory web pages.

3.3 Creating Framework for Evaluating the Effect of the Changes

The third objective was to develop means for evaluating the effectiveness of the changes that were implemented to fulfill the second objective. It was decided that this should be done through the utilization of two types of surveys – one for the new students, which is identical to the initial survey used to complete the first objective, and the other one for the students who have already completed the labs. This way it will be easier to see if the problems that were addressed in this project have made a positive difference. This objective was completed by creating an additional survey for the students who already completed the labs and took the initial survey.

4. Results and Analysis

The overall goal of this Interactive Qualifying Project was to enhance the online laboratory component for Professor Lemone's Compilers course. The survey that was designed in order to fulfill the first objective of gathering feedback from the students, provided information that was sufficient to create a clear picture of what the next evolutionary phase of the online laboratories should concentrate on. It also served as a precursor for completing the second objective of updating the laboratory source code.

4.1 Identifying Areas that Need Improvement

As was mentioned before, at the time of this writing the Compiler online laboratories are fully functional. They contain four different components that are designed to teach the students the fundamental techniques that will be needed in order to create a functional compiler at the end of the course, using two essential software packages – Lex and Yacc (see Appendix C for description of these tools).

Since the users of these labs do not strictly need to know the intrinsic details of invocation and execution of these tools, one of the most important aspects of these laboratories is the ability to provide an intuitive interface that will serve as an interactive input mechanism to get the data from the users and an output mechanism, that is able to visually represent the results of the code in a consistent and clearly understandable manner. Seamless user experience from data entry until final result presentation is critically important for this interactive lab.

4.1.1 Survey Results

Due to relatively small class size, only twelve people participated in the survey. The results, however, allowed to identify common themes, which lead to believe that the majority of the students had similar experience with the laboratories and had similar expectations in regards to possible improvements.

Remarkably, none of the students reported any problems with the overall functionality (based on the answers to question #1). Based on this, no changes were necessary for the back-end functionally of the laboratories.

The answers to the second question indicated two potentially problematic areas:

- Existing color scheme that was used on the laboratory pages made the text hard to read
- Results of the laboratory code weren't updated on the current web page, without actually refreshing the whole page

The answers to the third question indicated that overall, the students were quite happy with the availability of an online laboratory component for the course. They stated that it did help a lot with completing the homework assignments and the projects, as well as serving as a useful tool for quickly testing the code for the projects, rather than doing it manually. It was concluded that none of the core functionality needs to be changed.

As it turned out, most of the students used it to reiterate their answer to question #2. However, a few suggestions asked for better compliance with the most recent Internet standards.

Overall, the amount and the kind of feedback received were sufficient to fulfill the first objective and served as a foundation to implement the second objective.

4.2 Updating the Laboratories Source Code

The task of updating the laboratory web pages involved two stages. The first stage required analysis of the survey results and translating them into working requirements. The second stage consisted of assessing strategies that would enable these changes to be effective.

4.2.1 Analysis of Survey Results

Before any actual work was done on the online laboratory web pages, the feedback provided by the students was analyzed. The common theme of the identified problems was end-user experience and can be further split into three categories, which will be explained below.

The first category involved the overall color scheme of the laboratory web pages. About 40% of the students mentioned that it was hard to read black text on dark-grey background. Since presentation is crucial to the overall user experience with the labs, it would be important to choose a color scheme that would make it easier for the users to read the instructions and review the program output.

The next area that was identified as needing improvement was the way the output results are presented. Prior page behavior was to reload the entire page when the "Edit the text and click me" button was pressed. As the result, the focus in the browser was set to the top of the page. To check the output, students would have to scroll the text. This created usability issues, especially with lab code that produces a lengthy output, which would require the users to scroll down the page extensively.

The last category consisted of updating the laboratory web pages to comply with the W3C XHTML 1.0 standard, which is very widely used and is highly encouraged today. The benefit of conforming to this standard is that XHTML being essentially the same as HTML enforces stricter rules that do not allow nearly the same amount of vagueness in tag placement. This lessens the chance that different browsers will interpret and output the pages differently and increases cross-browser compatibility, which is very important for a distance learning class, since there is no control over what kind of browsers the students will use.

4.2.2 Implementation Strategies and Web Pages Modification

In order to come up with implementation strategy for the first category, existing web pages were thoroughly analyzed. During this process, it was determined that the styling directives were built into individual pages, even though their overall design was essentially the same. Possible implementation strategies in this case would be to update each page individually or modify them to rely on a common style sheet and make required color changes there. The downside of the first approach is that it would complicate further maintenance of the laboratory pages, because whenever a

new design needs to be implemented, it would have to be repeated for all four HTML parts of the lab, as well as their corresponding CGI files.

With the alternative design only external style sheet file would need to be modified, simplifying experimentations with various color schemes and further maintenance. An added benefit is also the fact that there will be a separation of presentation from content. Therefore, this implementation strategy was chosen. A new file was created, called style.css which contains the styling information about the key elements present in the labs (including background and text colors). Existing pages were modified to utilize the new CSS file for styling.

With the addition of an external style sheet, it became an easy task to alter color schemes of the lab pages. A few different schemes were tried, and white on black was determined to be the best choice for an educational site. This is the predominant color scheme that can be seen in printed items, such as books and the majority of the Internet.

While closely reviewing and updating the web pages source code, I discovered additional opportunities for improving visual page presentation. Among those:

- Introduce additional markup to better emphasize the logical sections of the page.
- Make better use of numbered and bulleted lists.

The description of the HTML tags that were used in order to improve the visual presentation of text is provided in detail in Appendix D.

The CGI pages were modified so that the generated output code appeared differently from the default text style. In addition, a grouping technique was employed to present executed commands and the generated output as an easily distinguishable logical group, separated from the rest of the page text (for details see Appendix D). This is illustrated on the figure below:

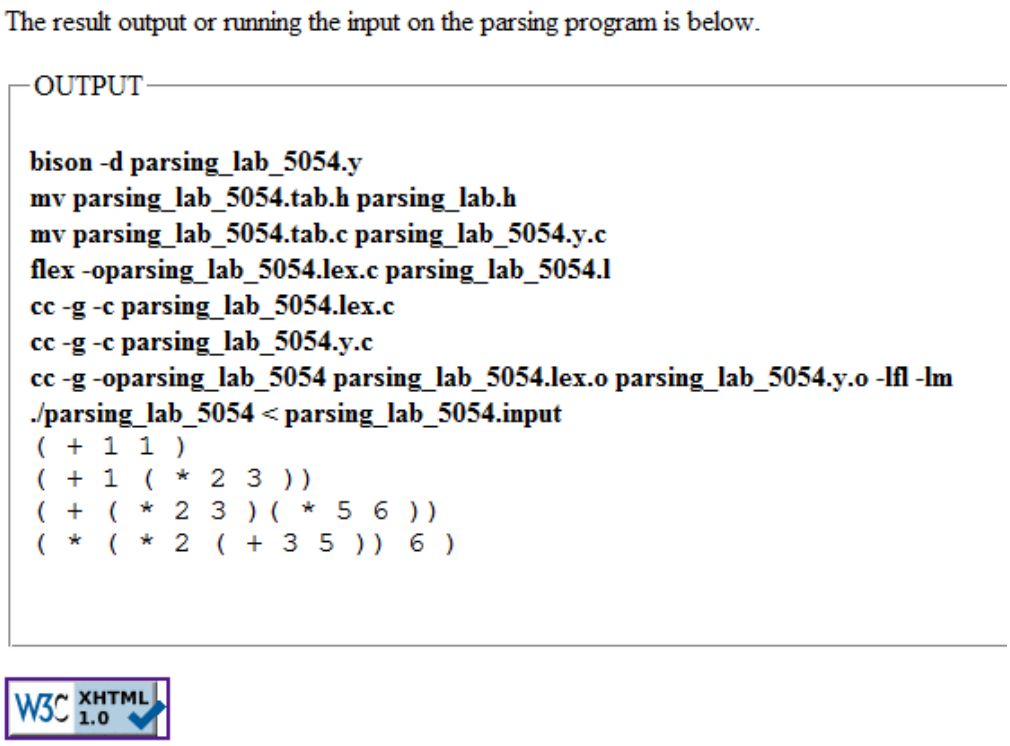

Figure 2 – Making Output More Visible

The same technique was used to emphasize the instructions, with commands and filenames appearing differently from the default text, and italicizing important words in order for them to stand out, which was done in order to improve readability.

Use of numbered and bulleted lists where appropriate provided for keeping the text more systematic, as illustrated on the figure below:

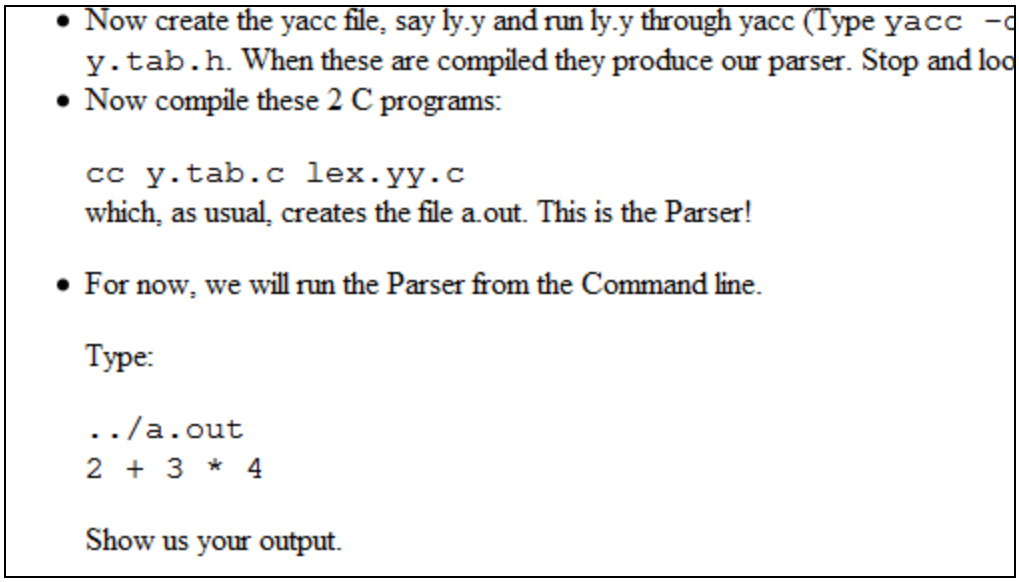

Figure 3 - Customizing Instruction Text

Once the color scheme and text markup customization were completed, the next logical step was to make the code contained in HTML files comply with XHTML 1.0 Strict. The only implementation strategy considered was code editing and verification of the changes using W3C validator service (validator.w3.org).

During the close examination of CGI files, it was found that they are already in compliance with this standard, and no code changes were required. As the result of the modifications to the HTML files, all the components of the online laboratories conformed to XHTML 1.0 standard, which will make them easier to maintain and avoid possible compatibility issues with various browsers.

To address the remaining issue with output results presentation, additional research was conducted. Two implementation strategies were considered:

- Adding an Ajax component into the Perl code that is responsible for generating the output for the labs

- Adding an anchor element into the HTML code that is being generated by the server

Ajax-based approach would impose an additional constraint on the type of browsers that the students can use. Because JavaScript implementations vary greatly across browsers, implementation complexity will be much higher, as well as potential for creating additional issues that the instructors will have to troubleshoot. The alternative strategy on the other hand, would only require introduction of a single HTML tag in the existing code. Even though technically this is not the same as asynchronously updating the page, this approach is useful because it is provides the same benefits of user convenience, without extra complexities of Ajax-based solution. Considering the scope of changes, the anchor tag approach was ultimately chosen. As the result, it eliminated the need for the users to manually scroll to the section of the page displaying the output. Appendix D provides additional detail about how this technique works.

At the later stages of implementation it became apparent that the navigation menu present on the main course site should be added both to the laboratories index page and to each of the laboratories as well. This navigation menu will allow the students to access the main course site, the "Modules", "Project", "Syllabus", and the laboratories index pages respectively to provide a consistent user experience with the main site. This navigation menu can be seen on the figure below.

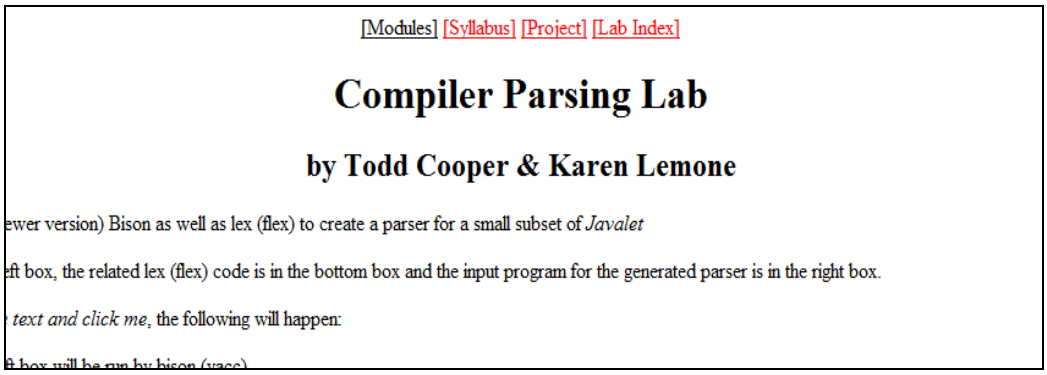

Figure 4 - Navigation Menu

4.3 Creating Framework for Evaluating the Effect of the Changes

In order to evaluate how useful the modifications described above are, it was decided that the most efficient way is to use two qualitative surveys. The reason for having two separate surveys is that ideally two different groups of people are needed to provide feedback. These two groups consist of the students who have already completed the class while using the previous design and the new group of students who will complete the laboratories with the new design.

Even though it was determined that the original survey could be improved, it was decided to keep it unchanged to simplify comparison of the results obtained from two different groups of students. If the issues that were raised in the past still exist, they will appear in the new results as well. If that is not the case, it is a good indicator that the efforts taken during this project were successful in providing a better user experience for the students who are taking the Compilers course.

Students who used the previous laboratory design would need a different kind of survey, the goal of which is to compare the two designs. In terms of its format, it

would be useful to have two sets of questions. The first set should contain Likert-scale questions that would allow rating the overall design of the laboratory web pages prior to this project vs. after the modifications were made. The other set of questions need to be open-ended, where the users can provide comments on what exactly made them choose one way or another and if there are still issues that should be addressed. This survey is presented in Appendix B.

Because of the fact that the changes were made throughout the duration of this project, no students have yet completed the course with the new design fully in effect. As a result, it was impossible to generate any feedback about the effectiveness of the modifications to the laboratory pages at the time of this writing. However this is an important step that will prove effective for generating feedback for further work on these laboratories.

5. Conclusions and Recommendations

The main goal of this Interactive Qualifying Project was to enhance a set of online laboratory web pages that Professor Lemone uses as part of her Compilers course, which is taught as both a traditional on-campus course and as a part of a distance learning program.

In order to satisfy this goal, three objectives were developed, whose completion determined how well the goal of enhancing the laboratory pages was achieved. The first objective was to identify areas that need improvement. A survey was used as a method for fulfilling this objective. It was used to gather feedback from the students who took the course in a classroom environment during C term of 2009. This feedback was then analyzed and the predominant set of ideas was chosen as a guideline for creating the list of items that would potentially benefit the laboratories.

The second objective was to update the laboratories source code, based on the results of the first objective. To fulfill this objective, different implementation strategies were analyzed and the most appropriate chosen and executed in order to provide a better user experience for the students who will take the Compilers course in the future.

In order to create a framework for evaluating the effect of the changes made to the online laboratories, which was the third objective, an additional survey was developed to target students who already provided feedback for the first objective. The purpose of this survey was to find out whether or not the changes improved the lab pages and what else could be done if this was not the case. The second survey

would need to be given to the new set of students taking this course, with the same questions as in Appendix A. Because of the time constraints, however, and the fact that this course was not offered during the time this project was concluded, there is currently no feedback from the types of users described above.

Potential future work on updating these pages depends on the responses of the students who have to use these online laboratories. There are also a few areas in visual presentation that could be improved in order to make these labs integrate better into Professor Lemone's main course web site.

Works Cited

Consortium, T. S. (2006). *Making the Grade: Online Education in the United States*. Retrieved May 4, 2009, from The Sloan Consortium A Consortium of Institutions and Organizations Committed to Quality : http://www.sloan-c.org/publications/survey/survey06.asp

Group, M. M. (2008). *North America Internet Usage Statistics, Population and Telecommunications*. Retrieved May 4, 2009, from Internet Usage World Stats: http://www.internetworldstats.com/stats14.htm

Jackson, J. C. (2007). *Web Technologies: A Computer Science Perspective.* Upper Saddle River, NJ: Prentice Hall.

Moisseeva, M. (2007). *Types and Forms of Distant Learning*. Retrieved May 6, 2009, from Institute of International Education: http://www.iienetwork.org/?p=41544

Moore, M. G., & Kearsley, G. (2005). *Distance Education: A Systems View (Second ed.). :* . Belmont, CA: Wadsworth.

The Lex & Yacc Page . (2009, April 29). Retrieved April 29, 2009, from The Lex & Yacc Page : http://dinosaur.compilertools.net/

The W3C Markup Validation Service. (2009, April 29). Retrieved April 29, 2009, from The W3C Markup Validation Service: http://validator.w3.org/

Toronto, U. o. (n.d.). *Server Processing of Passed Data: Gateway Programs*. Retrieved May 5, 2009, from Introduction to The Common Gateway Interface: http://www.utoronto.ca/webdocs/CGI/cgi2.html

White, M. (2007, May 29). *The Best of Both Worlds - Combining E-Learning with Traditional Instructional Methods*. Retrieved May 6, 2009, from E Learning Blog: http://www.elearning-avenue.com/the-best-of-both-worlds-combining-e-learning-with-traditional-instructional-methods/

Appendices

Appendix A: Compiler Lab Survey

1. Was there something in particular that didn't work for you while completing the labs (please mention if it only applied to a particular lab)?

2. Were there any specific issues that you have faced from a basic usability/interface point of view?

3. What did you like most about the labs? Were they a useful tool for completing the various parts of the project? If not, state why.

4. Do you have any suggestions on what could be done to improve the format of the labs?

Appendix B: Comparison Survey For Former Students

1. Rate on a scale from one to five your preference of the new design over the old design, with 1 denoting preference of the old design and 5 – the new design.

   (1) (2) (3) (4) (5)

2. Was the addition of a navigation bar helpful? Please circle one of the options below.

   True **False**

3. Did the changes cause any problems that were not present before? If so, explain.

4. Do you have any suggestions for further improving the laboratory pages?

Appendix C: Lex and Yacc

Below is the description of the capabilities that the tools Lex and Yacc provide (The Lex & Yacc Page, 2009).

Lex - A Lexical Analyzer Generator

M. E. Lesk and E. Schmidt

Lex helps write programs whose control flow is directed by instances of regular expressions in the input stream. It is well suited for editor-script type transformations and for segmenting input in preparation for a parsing routine.

Lex source is a table of regular expressions and corresponding program fragments. The table is translated to a program which reads an input stream, copying it to an output stream and partitioning the input into strings which match the given expressions. As each such string is recognized the corresponding program fragment is executed. The recognition of the expressions is performed by a deterministic finite automaton generated by Lex. The program fragments written by the user are executed in the order in which the corresponding regular expressions occur in the input stream.

Yacc: Yet Another Compiler-Compiler

Stephen C. Johnson

Computer program input generally has some structure; in fact, every computer program that does input can be thought of as defining an ``input language" which it accepts. An input language may be as complex as a programming language, or as simple as a sequence of numbers. Unfortunately, usual input facilities are limited, difficult to use, and often are lax about checking their inputs for validity.

Yacc provides a general tool for describing the input to a computer program. The Yacc user specifies the structures of his input, together with code to be invoked as each such structure is recognized. Yacc turns such a specification into a subroutine that han- dles the input process; frequently, it is convenient and appropriate to have most of the flow of control in the user's application handled by this subroutine.

Appendix D: Important HTML Elements

HTML standard provides several useful tag elements that can change text styles in order to improve readability. For this project, the following were used:

- - This tag is used to emphasize certain words or phrases. Usually the words appear italicized, but that is up to the browser's interpretation.

- <code> - The <code> tag is used to distinguish text that represents a command or a snippet of computer code, generally decorated with a mono-spaced font. It is very useful for this project because of the significant number of commands and file names referenced in the instructions, as well as for the rendering of the output that is generated by the labs.

- <fieldset> - This tag provides a mechanism for logical grouping of elements. The text that is being grouped appears within borders that separate it from the rest of the page. For this project, in addition to the <code> tag that is described above, this technique is used to make the output stand out from the rest of the text on the page to provide for better readability.

- <a> - Anchors are useful for page navigation. An anchor is placed within a web page and can then be used to automatically bring the focus of the user's browser to a particular location on the page. In this project that approach is used to focus the page on the command output. A reference to the anchor is passed with the POST action that is fired every time the "Edit text and click me" button is pressed. When the new page is rendered in the student's browser, it automatically

positions to the location defined by the anchor, as a result eliminating the need for the users to manually scroll to the section of the page displaying the output.