CASTLE:
COMPUTER ARCHITECTURE SELF-TESTING AND LEARNING SYSTEM

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Abstract. *The paper introduces the CASTLE, a Web-based system for **C**omputer **A**rchitecture **S**elf-**T**esting and **LE**arning. The CASTLE offers self-testing and learning facilities meant to be used by students at home and/or in lab in the process of studying and exam preparation. It also offers a rich set of facilities to help the system administration and to provide feedback to instructors. The core of the CASTLE tool is developed using zero-cost environment, in such a way that it could be easily modified and used for teaching other courses.*

I INTRODUCTION

The Internet has dramatically changed the way instructors teach Computer architecture and organization, and the way students learn. Modern software tools enable the development of Web-based graphical animations to illustrate complex topics [1], advanced computer architecture CAD tools have become available via Web browsers [2], and collections of course material including tests and exams can be shared between instructors [3].

Web-based testing plays an important role in distance learning. For example, the IEEE Computer Society has recently started to offer to its members various courses as a part of the Distance Learning Campus [4]. We feel that "classic" classroom- and lab-based courses could also benefit from the opportunity of online testing and self-assessment and that is why we are building the CASTLE, a Web based software system for Computer Architecture Self-Testing and Learning.

Previously we made some efforts in the similar direction by developing the CALKAS [5]. However, it uses rather expensive commercial environment, and it is primarily targeted to the assessment of the student knowledge during labs.

The CASTLE offers the students an opportunity for online testing on various topics in computer architecture and organization, anytime, anywhere. Using this tool, students can continuously reinforce their classroom learning, and can get valuable feedback about their course advancement. The CASTLE allows students to choose the level of testing. At the beginning they can start with elementary questions, and as they progress through the course they choose more complex tests at the medium and advanced levels. Each question is tagged with an explanation field, which includes a full explanation or a link to the corresponding textbook or material on the Web.

The CASTLE allows instructors a Web-based administration by using simple forms to insert, edit, or delete information about students and questions. In addition to that, the CASTLE can generate various statistics from the database providing the instructors with valuable feedback about students' advancement. Using these statistics, instructors can identify what is difficult for students to grasp. Often instructors have groups of students with different background and inhomogeneous knowledge. In such cases the CASTLE should help those with insufficient prerequisites to catch up. Thanks to explanations it provides, the CASTLE as a "virtual instructor" could improve the overall quality of teaching since it gives the instructor more time to spend on difficult topics.

The CASTLE is developed using Java Servlet/Java Server pages technologies and MySQL as a database. We have developed and tested the core of the CASTLE and now we are building the database with questions. The rest of the paper is organized as follows. In Section 2 we describe the facilities offered by the CASTLE. Section 3 gives a short overview of the CASTLE internals. Section 4 concludes.

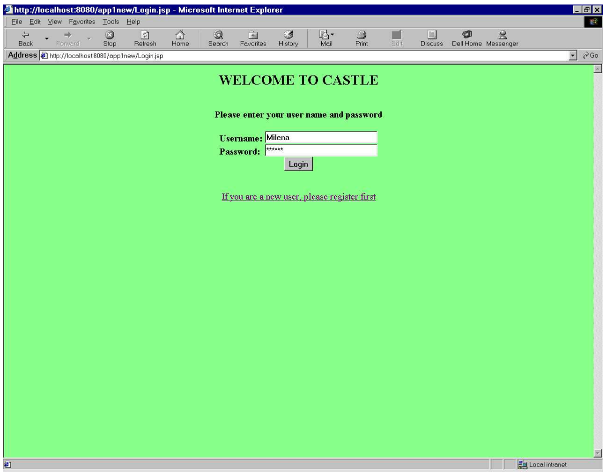
II USING CASTLE

The CASTLE offers two levels of functionality:

- At the user level, it provides self-testing facilities to students, and
- At the administrator level, it provides administration facilities to instructors.

The user level

The first step in working with CASTLE is to login: a user enters her/his username and password, and activates **Login** button (Figure 1). The system checks whether a user with that username exists in the database of users and whether the password is correct. If the login is successful, the system allows access to self-testing mode, and the Welcome screen appears (Figure 3). New users are asked to register first (Figure 2).


File Edit View Favorites Tools Help
Back Forward Stop Refresh Home Search Favorites History Mail Print Edit Discuss Dell Home Messenger
Go
Local intranet

http://localhost:8080/app1new/Login.jsp - Microsoft Internet Explorer

Address http://localhost:8080/app1new/Login.jsp

WELCOME TO CASTLE

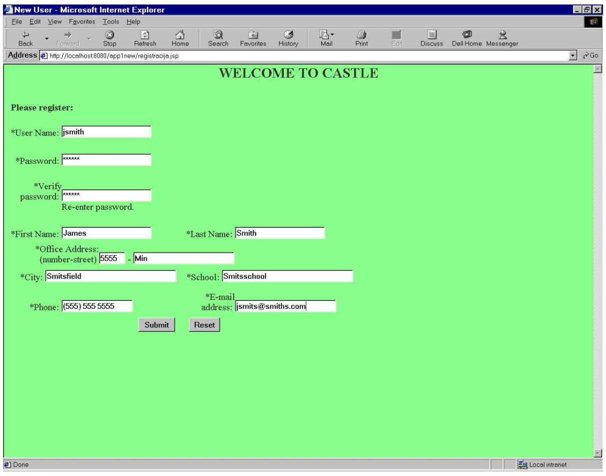
Please enter your user name and password

Username: Milena
Password: ******

Login

If you are a new user, please register first

Figure 1. Login screen.


File Edit View Favorites Tools Help
Back Forward Stop Refresh Home Search Favorites History Mail Print Edit Discuss Dell Home Messenger
Go
Done
Local intranet

New User - Microsoft Internet Explorer

Address http://localhost:8080/app1new/registracija.jsp

WELCOME TO CASTLE

Please register:

*User Name: jsmith

*Password: ******

*Verify password: ******
Re-enter password.

*First Name: James *Last Name: Smith

*Office Address: (number-street) 5555 - Min

*City: Smitsfield *School: Smitsschool

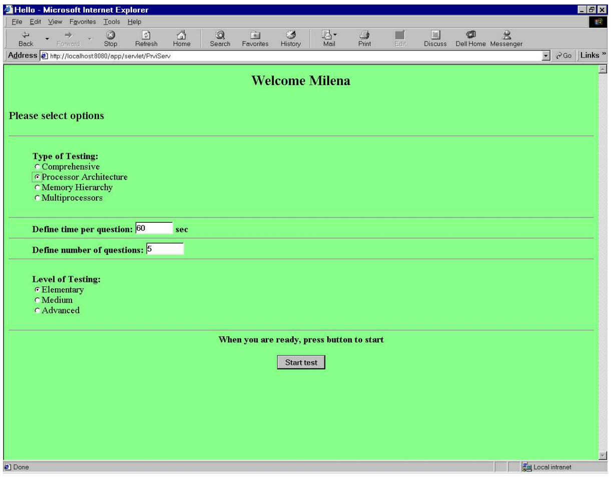
*Phone: (555) 555 5555 *E-mail address: jsmits@smiths.com

Submit Reset

Figure 2. Register screen.

The Welcome screen offers the user possibility to select the type of testing; the current version of the CASTLE supports the following types: Comprehensive, Processor Architecture, Memory Hierarchy, and Multiprocessors. The user also defines test duration (test time per question), the number of questions in the test, and the level of testing. The CASTLE currently supports three levels of testing: *Elementary*, *Medium*, and *Advanced*.

The test is then activated using the **Start test** button. The CASTLE generates randomly requested number of questions with offered answers from the database; all questions generated have the same difficulty tag (Elementary, Medium, or Advanced). The questions appear one by one. For each question the remaining time is counted-down in real time and displayed on the screen (Figure 4). Questions may include graphical content. The user answers the questions by activating the appropriate check box in front of the answer deemed to be correct.


File Edit View Favorites Tools Help
Back Forward Stop Refresh Home Search Favorites History Mail Print Edit Discuss Dell Home Messenger
Go Links »
Done
Local intranet

Hello - Microsoft Internet Explorer

Address http://localhost:8080/app/servlet/PrviServ

Welcome Milena

Please select options

Type of Testing:
○ Comprehensive
● Processor Architecture
○ Memory Hierarchy
○ Multiprocessors

Define time per question: 60 **sec**

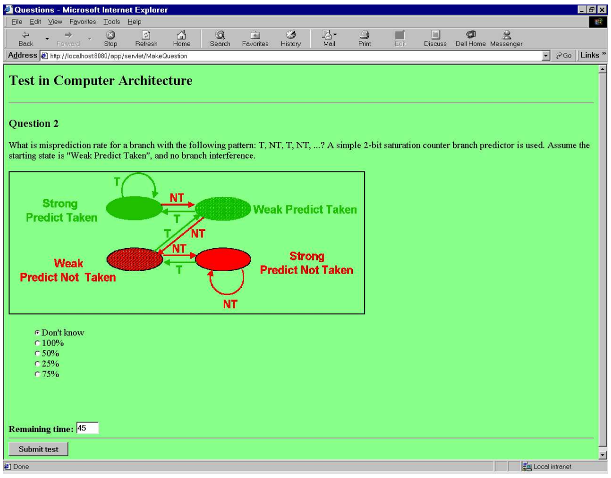
Define number of questions: 5

Level of Testing:
● Elementary
○ Medium
○ Advanced

When you are ready, press button to start

Start test

Figure 3. Welcome screen.


File Edit View Favorites Tools Help
Back Forward Stop Refresh Home Search Favorites History Mail Print Edit Discuss Dell Home Messenger
Go Links »
T
NT
Strong
Predict Taken
Weak Predict Taken
T
T
NT
NT
Weak
Predict Not Taken
T
Strong
Predict Not Taken
NT
Done
Local intranet

Questions - Microsoft Internet Explorer

Address http://localhost:8080/app/servlet/MakeQuestion

Test in Computer Architecture

Question 2

What is misprediction rate for a branch with the following pattern: T, NT, T, NT, ...? A simple 2-bit saturation counter branch predictor is used. Assume the starting state is "Weak Predict Taken", and no branch interference.

● Don't know
○ 100%
○ 50%
○ 25%
○ 75%

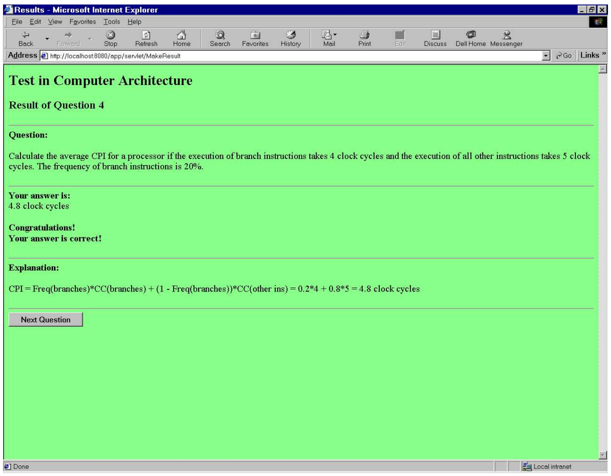
Remaining time: 45

Submit test

Figure 4. Test screen.

When the user has completed a question, even if the time predetermined for giving an answer has not yet expired, she/he can submit the test by activating the **Submit test** button. If the test has not been submitted within the predetermined period of time, the CASTLE stops the testing when the time expires and the user is asked to submit the answer. The CASTLE checks correctness of the given answer and generates a result screen including the question, given and the correct answer, and explanation for the correct answer (Figure 5). By activating the **Next Question** button the test continues.

The information concerning the completed test, such as the user's identification number, the date, the time, the generated questions, and the given answers, are saved in the appropriate database tables. Hence, any relevant information concerning all tests taken by any user can be obtained at any time.


Results - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Back Forward Stop Refresh Home Search Favorites History Mail Print Edit Discuss Dell Home Messenger
Address
Go
Links
Next Question
Done
Local intranet

http://localhost:8080/app/servlet/MakeResult

Test in Computer Architecture

Result of Question 4

Question:

Calculate the average CPI for a processor if the execution of branch instructions takes 4 clock cycles and the execution of all other instructions takes 5 clock cycles. The frequency of branch instructions is 20%.

Your answer is:
4.8 clock cycles

Congratulations!
Your answer is correct!

Explanation:

CPI = Freq(branches)*CC(branches) + (1 - Freq(branches))*CC(other ins) = 0.2*4 + 0.8*5 = 4.8 clock cycles

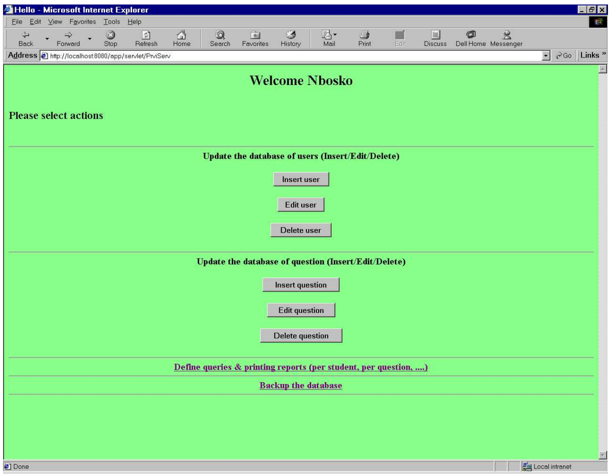
Figure 5. Result screen.

When the user has completed the test she/he can get the final test report. This report contains the score and a table with all questions from the test, the answers given and the correct ones. At the end of the test, the user can start new test session by activating **New test** button.

The administrator level

At the administrator level instructors use the CASTLE to maintain the database including information regarding users, questions and offered answers, and test sessions. The CASTLE provides simple forms that can be used to enter new questions and update the list with answers, modify the list of offered answers, add, edit, and remove users. In addition to that, the CASTLE allows instructors to generate and print the itemized reports including statistics - number of tests taken, percentage of correct answers, etc., for each topic (e.g., Memory hierarchy), and for each question. Finally, the CASTLE allows instructors to backup the whole database.

The first step for an instructor is to login by entering administrator username and password; Administrators use the same Login screen as ordinary users (Figure 1). After a successful login the Welcome administrator screen appears (Figure 6). From this screen the administrator can select any of the available functions: **Insert User** to add a new user, **Edit User** to edit information about a user, **Delete User** to remove a user from the database of users, **Insert Question** to add a new question in the database, **Edit Question** to edit relevant fields of a question, **Delete Question** to remove a question from the database, **Define Queries & Printing Reports** to create and print various reports, and **Backup** to backup the database.


Hello - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Back Forward Stop Refresh Home Search Favorites History Mail Print Edit Discuss Dell Home Messenger
Address
Go
Links
Insert user
Edit user
Delete user
Insert question
Edit question
Delete question
Done
Local intranet

http://localhost:8080/app/servlet/PrviServ

Welcome Nbosko

Please select actions

Update the database of users (Insert/Edit/Delete)

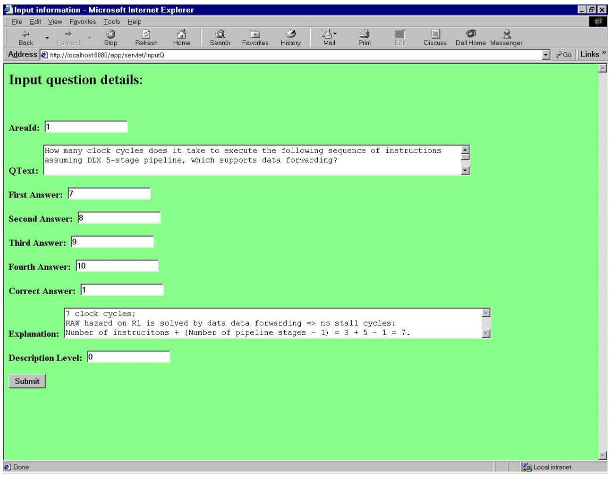
Update the database of question (Insert/Edit/Delete)

Define queries & printing reports (per student, per question, ...)

Backup the database

Figure 6. Administrator Welcome screen.

Insert Question and **Insert User** buttons bring screens containing all relevant fields to be defined for a new question and a new user, respectively. Figure 7 shows the form for entering a new question. The instructor enters relevant fields such as the text of the question, offered answers (up to four possible answers), Id for the correct answer, Id for the area, the level of difficulty, and the explanation. All fields are checked for consistency before the database is updated by activating **Submit** button.


Input information - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Back Forward Stop Refresh Home Search Favorites History Mail Print Edit Discuss Dell Home Messenger
Address
Go
Links
Submit
Done
Local intranet

http://localhost:8080/app/servlet/InputQ

Input question details:

AreaId: 1

QText: How many clock cycles does it take to execute the following sequence of instructions assuming DLX 5-stage pipeline, which supports data forwarding?

First Answer: 7

Second Answer: 8

Third Answer: 9

Fourth Answer: 10

Correct Answer: 1

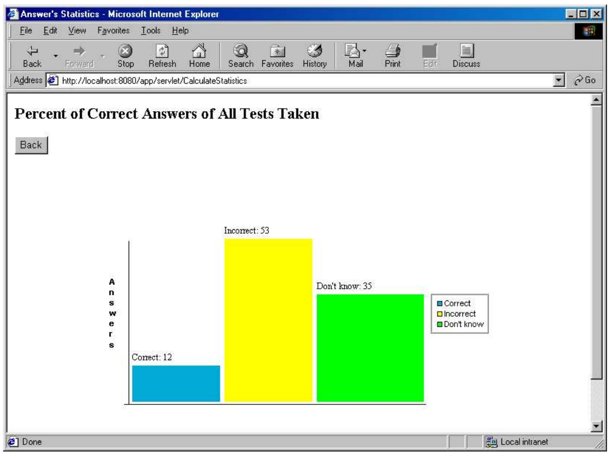
Explanation: 7 clock cycles;
RAW hazard on R1 is solved by data data forwarding => no stall cycles;
Number of instrucitons + (Number of pipeline stages - 1) = 3 + 5 - 1 = 7.

Description Level: 0

Figure 7. Insert Question screen.

Edit Question and **Edit User** forms require the questionID and username to be entered by the instructor, respectively. Complete record appears on the screen, and all fields can be changed. Changes become visible by activating the **Submit** button. Similarly, the instructor can remove a user or a question using **Delete User** and **Delete Question** forms.

By activating **Define Queries & Printing Reports** button instructor opens a new form where she/he selects a query, such as global statistics, and statistics per area, per question and per user. The result screen will contain required information, including statistic charts (Figure 8). The instructor prints the report by activating the **Print** button.


Answer's Statistics - Microsoft Internet Explorer

Address http://localhost:8080/app/servlet/CalculateStatistics

Percent of Correct Answers of All Tests Taken

Done

Figure 8. Statistics screen.

III INTERNALS OF THE CASTLE

Primary requests for the development environment were to support all facilities of the CASTLE as well as to minimize the cost. We use a zero cost environment based on Java Servlet and JavaServer Pages (JSP) technologies [6]. As a Web server we use Tomcat [7], a free open-source implementation of Java Servlet and JavaServer Pages technologies developed under the Jakarta project at the Apache Software Foundation. We use MySQL [8], a free, open source database available for many computing platforms. It represents the most affordable solution for relational database services available today. For communication between Java servlets and the database we use, a free JDBC driver mm.mysql-2.0.4-bin.jar [9].

Figure 9 shows the development environment and illustrates the data flow. We decided to implement a rather simple graphical interface, so the CASTLE can be accessed without any delay even over 56K modem connections.

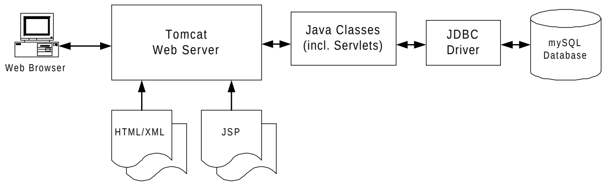


Figure 9. Development Environment.

IV CONCLUSION

This paper introduces the CASTLE, a Web-based system for testing in computer architecture and organization. It allows students to test their knowledge continuously throughout the course giving them full control over the number of questions they want to take, test difficulty, and course topics. In addition to that the CASTLE facilitates the system administration and provide valuable feedback about course advancement to instructors during the course. The development environment guarantees simple user interface, flexibility, and security of data, availability, maintainability and upgradeability.

The primary short-term goal is to expand the current number of questions and to support different question forms in addition to multiple choice. The next step will be to open the gates of the CASTLE to broader community, to all interested to improve their knowledge in computer architecture.

ACKNOWLEDGEMENTS

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[8] http://www.mysql.com/

[9] http://mmmysql.sourceforge.net/