CHAPTER 8

PROTOTYPE ARCHITECTURE AND IMPLEMENTATION

**Objective**: The practical demonstration is presented in this chapter through using a novel prototype architectural model based on MVC design pattern. The practical investigation is a web based e-learning application, to provide suitable content to different client devices. The practical approach presented in this chapter is mainly based on proposed approaches and methodology that has been covered in various chapters in this dissertation as précised below.

Due to computational and technical barriers most of the current e-learning applications and their learning contents are not suitable for mobile devices. To facilitate development of context-aware application, **Chapter 5** discussed the technical pattern for context detection and description mechanism, which is an essential constituent in context-aware adaptive e-learning system to deliver suitable content based on device type.

To locate the learning content as per the contextual information presented in Section 5.6, the resource description model called Context-aware Adaptive Learning Resource Ontology (CALRO) is being introduced in **Chapter 6**. The proposed CALRO ontology allows the adaptive delivery mechanism to deliver suitable contents according to the learner’s contextual information.

To attain the desired adaptive delivery, an ontology based context-aware adaptation mechanism, based on rules that are derived from context ontology is discussed in **Chapter 7**, where we mentioned the possible adaptation scenario, expressed in Semantic Web Rule Language (SWRL) to obtain an adaptive course content delivery process.
8.1 Introduction

In an adaptive e-learning environment, the system must respond harmoniously to the changes of learner needs, learning style and context. The e-learning approach such as online learning empowers the students for self-learning and to create personalized context aware adaptive learning approaches, through leveraging the huge digital learning resources that are available on the internet. The recent, emerging mobile communication technology and the popularity of mobile solutions have geared the traditional PC based e-learning approach to increase their change to m-learning, but the divergence between these two types of environments based on their technical capabilities and characteristics has become a paradox to use existing digital learning contents and applications that are developed with the perspective of computers. Therefore, various content adaptation (transcoding) techniques have emerged to perform the adaptation of learning contents based on the characteristics of learning devices. These single-source adaptation techniques often lead to high complexity and cumbersome task to deliver the adapted contents dynamically as per the characteristics of client device. This needs to develop multi-source authoring contents, where separate resources are maintained for each class of device. In the proposed prototype implementation we are considering only two types of resources as compatible for PC and mobile environments. Here, the researcher has proposed an architectural framework for context aware adaptive content delivery for course based e-learning environments. The novel feature of this architectural approach is that it uses the recent MVC – Model View Controller (Deacon, 2009) architectural design pattern that provides the benefits such as code reusability, upgradability and multiple views of the same data. Another important feature is ontology-based learner context model that helps in accessing the concepts that are contextually and conceptually suitable for learner needs.
8.2 Objectives of Proposed Approach

The main objective of the proposed system is to improve the learner’s knowledge and to facilitate the learner to review course contents at any moment of time. The development of new generation of e-learning applications has to leverage the technical advancements in digital learning devices to obtain potential benefits. Here, two important technical strategies such as ontology based content organization and presentation and device independent adaptive delivery have been noticed and these are to be considered while developing the new generation of e-learning applications. The two strategies and their respective targets and benefits are as shown in Table 8.1.

Table 8.1 Objectives of proposed approach

<table>
<thead>
<tr>
<th>Strategies</th>
<th>Target</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ontology based content organization and presentation of course material</td>
<td>Increasing learners understanding capability, critical thinking and problem solving skills.</td>
<td>Providing foundation material, such as prior and related materials of current learning concept.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Extends learning beyond the stipulated course contents.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Learner can navigate and read all other concepts which are conceptually related to course contents.</td>
</tr>
<tr>
<td>Device independent adaptive delivery of learning resources</td>
<td>Increasing student engagement towards learning course.</td>
<td>Learner can read class material that is not offered or covered in regular classes.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Learner is able to review materials as many times as needed.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mobile-learning helps learner, to review course material at any moment of time and place, whenever and wherever they want, so it will improve student engagement in learning.</td>
</tr>
</tbody>
</table>
8.2.1 Ontology based Content Organization and Presentation

An ontological approach provides the management and organization of course material based on their semantic inter relationships in order to improve the understanding ability of the learner. This can also help e-learning application developers to search and present related knowledge of a particular learning topic. It is ambivalent to make the learner ambulate among learning concepts with one perspective. It is willingness of the learner to navigate based on his cognitive skills and learning style. As proposed by Brusilovsky and Vassileva (2003) the pool of course concepts are connected to form heterarchy (where items are likely to be related in two or more differing ways. For example: “Trees” is a topic concerned with “Data Structure” subject while it is a sub concept of “Graphs” and Traversal is the operation performed on Trees) as shown in Figure 8.1.

Figure 8.1 Interrelation among pool of concepts

Learner may have different viewpoints, cognitive skills, and knowledge levels of learning materials (Daqing et al., 2006) and as mentioned by Dicheva and Dichev (2004) the students are often unaware of the context of the
learning task when they start to learn new concepts. The proposed presentation approach makes the learner to learn and interpret the correlated and in-depth concepts of learning domain so that the learner gets exposed to higher order thinking skills and makes him professional in the discipline.

Course structure ontology:
The ontology based knowledge modeling and presentation of course contents facilitates the learner to understand everything related to particular learning concept. The graphical representation of various topics of proposed course ontology can be formally denoted by $G (T, P, R)$, where

$T = \text{Set of topics of specific course or subject;}$
$P = \text{Property set such as ID, Name, Description, etc.;}$
$R = \text{Relation set indicating the semantic relationships between the pair of concept is as shown in Figure 8.2.}$

![Figure 8.2 Partial course structure ontology](image-url)
For example, consider the subject “Data Structures” It can act as “Course class”, some of the “Topic classes” and their conceptual relations with various concepts are shown in Table 8.2.

Table 8.2 Ontological description of “Data Structures” subject

<table>
<thead>
<tr>
<th>Topics (Topic classes)</th>
<th>Related Concept (hasRelatedConcept)</th>
<th>Sub Concept (hasSubConcept)</th>
<th>Applications (hasApplication)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trees</td>
<td>Graphs, Traversal, Algorithms</td>
<td>Binary trees, AVL Trees,</td>
<td>Heap Sort, Directory</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Traversal</td>
<td>Structure</td>
</tr>
<tr>
<td>Stacks</td>
<td>Queues, List, Arrays</td>
<td>PUSH, POP</td>
<td>Recursion, Buffer Storage,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>DFS</td>
</tr>
<tr>
<td>Queues</td>
<td>List, Arrays</td>
<td>D-Queue, P-Queue</td>
<td>Multi-tasking, BFS</td>
</tr>
<tr>
<td>Graphs</td>
<td>Trees, Network, Maps</td>
<td>Traversal, BFS, DFS</td>
<td>Multi Processor Scheduling, PERT-Network</td>
</tr>
</tbody>
</table>

8.3 Design Pattern of Proposed Architecture

MVC\(^{40}\) (Model–View–Controller) architectural design pattern is one of the recent developments in Microsoft ASP.NET technologies. As we are aiming to develop web based e-learning system, this approach isolates the application logic from the users input and presentation (User Interface) environment, so that using this model in the architecture of proposed context aware adaptive e-learning system, it can offer dynamic content adaptation to provide various presentation formats for various client devices.

\(^{40}\)MVC: http://www.asp.net/mvc
According to MVC system, the main components are M (Model), V (View) and C (Controller) which can be defined as:

- **Controller**: It handles the user interaction and input logic received from View and based on Model.
- **Model**: Handles the business logic (rules) and data. It is independent of other parts of Controller and View.
- **View**: Is an output representation of Model data and View knows only about Model.

The generic MVC design pattern (ASP.NET MVC 4 in Action, 2012) has been modified so as to make it suitable for context aware adaptive e-learning system, as shown in Figure 8.3.

![Figure 8.3 MVC based design pattern for context aware system](image-url)
8.4 Architecture of System

The architecture of the proposed context aware adaptive system is developed based on the MVC design pattern as discussed in the previous section; the three different components and their relation are as shown in Figure 8.4.
The functionality of these components in the proposed context aware adaptive e-learning system architecture is:

**Controller (Context detection and adaptive mechanism):**

The controller is responsible for noticing what type of learning device it has received the request from and then it redirects to suitable view (web page). The events that are occurring through learner interaction should be captured by the controller and trigger the relevant events to change the model.

**Model (Information storage and query processing):**

It describes learner context, adaptation logic and learning content repositories. Based on adaptation logic it feeds suitable data to the View and it responds based on the context information received from controller and notifies the View to update the display.

**View (User Interface):**

It is an output representation of model data and is considered as dumb. In the proposed system, it is a web browser with internet connection. View knows only about Model so it can present data based on Model.

In the context of proposed context aware adaptive e-learning system architecture, the client device sends HTTP request to Web Server (e.g. IIS). The context detection mechanism (Controller) implemented in web server receives the request and identifies the device type based on the User Agent profile headers. The device context gets stored along with learner preferences under relevant learner context-id as learner context information (Model).
When the learner accesses the learning contents, the Controller’s Action class passes request to adaptation logic that is responsible for delivering suitable content from the relevant database and as per the presentation logic (View) that is based on the device context and learning style of the e-learner.

8.5 System Description

To evaluate the proposed MVC oriented architecture model for context aware adaptive delivery of learning resources, the researcher preferred to develop course based e-learning prototype application. This web-based prototype is implemented to deliver the contents based on contextual information such as device properties and learner preferences. The desired goal of proposed system is not just a function of how the course material is organized and delivered, but to influence and initiate learner’s learning process so as to acquire new knowledge through presenting conceptually related information of current learning concept. The delivery of the content is based on learner context to reduce the precision of search results.

8.5.1 Test bed Scenario

The proposed system is designed and developed in such a way as to recognize whether the accessing device is Mobile or PC and then it redirects the learner to the suitable web pages. The redirection of the learner to device specific URL is based on the User Agent in the HTTP request headers. An example of “HTTP header” and “User Agent” formats is shown in Table 8.3.
Table 8.3 Example of “HTTP-header” and “User Agent”

An example of HTTP header of PC-Client looks like this:
Connection=keep-alive
Accept-Encoding=gzip
Accept-Language=en-US
Host= http://localhost/Default.aspx
User-Agent= Mozilla/5.0 (Windows NT 6.1; rv: 22.0) Gecko/20100101 Firefox/22.0

An example of User Agent of PC 2003 SE Emulator:
Mozilla/4.0 (Compatible; MSIE 4.01; Windows CE; PPC; 240 x 320)

In the proposed system the optimized web pages are designed based on the presentation capabilities of feature-phones and smart-phones and the test bed scenario is shown in Figure 8.5.
8.5.2 Working Process of System

Given below are the various steps involved in the working process of the proposed system and its relevant flowchart is as shown in Figure 8.6.

Pre requisites:
The student needs to undergo the registration process through form filling approach that collects personal details of the learner and allocates user-id and password for authentication purpose. The learner has flexibility to use any type of learning device such as mobile or PC as the system is designed to detect device context automatically.

Device detection:
System detects the device type using User Agent profile of HTTP request received from client machine and it is considered as device context.

Acquiring learner style:
The learner needs to enter the preferences and learning style before starting to do particular course.

Course selection and navigation:
Learner needs to select his preferred course of learning from list of courses; then the system provides concepts of the selected course and the learner can navigate through concepts, sub concepts and so on.

Content delivery:
When the learner searches for a particular topic, the system retrieves the content from content repository along with details such as related concepts, examples, etc., based on resource description ontology.
8.6 Prototype Implementation

Here, the experimental results of the proposed web based prototype that is being implemented in our university are presented. The system presents the relevant learning material according to the device context. Figure 8.7 illustrates the PC client, Feature phone (WAP based device) and Smart phone (such as
iPhone) execution results of the proposed context-aware content adaptation approach (Screenshots of Login Screens and Course Structure are shown in Appendix 4). For mobile environments the content-adaptation mechanism delivers the content through breaking the webpage into several large chunks of text.

The course content presentation approach consists of base concept and other semantically related concepts that can improve the learner performance and the student has the option to freely navigate using any of the onscreen links of the relevant concepts.

Figure 8.7 Prototype implementation in different access devices
8.7 Evaluations and Results

The primary purpose of the proposed adaptive system is to provide context aware e-learning environment to learn and navigate through course topics concerned with the course curriculum. The distinct feature of the proposed system is, when the learner navigates to a particular concept, the learner is able to view other topic titles that are conceptually related to current learning topic (as shown in Figure 8.7) which improves the understandability, knowledge level and cognitive skills of e-learner. To evaluate the proposed approaches as a proof of concept, the researcher has implemented a web-based prototype in the research center of computer science department in his university. The experiment is performed in an intranet enabled environment using local university database as data-set for learning materials.

8.7.1 Experimental Design

Here, the two different categories of experiments/surveys are conducted to address the following:

- Performance Evaluation (by experiment)
- Usability Evaluation (by survey)

The purpose of the first experiment is to evaluate the performance of the proposed e-learning system through utilizing statistical approach, pre-test and post-test experimental design. The researcher preferred to test the difference of achievements between the experimental group and the control group using one-way Analysis of Covariance (ANCOVA) as it makes the group comparisons more “fair” (Owen, 1998). The second experiment is the survey, to investigate the degree of student’s satisfaction on proposed system. It involves collecting the
opinion of students who participated in the previous performance evaluation study.

### 8.7.2 Performance Evaluation

In this study, the aim was to determine whether the proposed system meet most learners’ requirements to promote their learning performance. To perform this test the course experts identified learning concepts on “Data Structures” subject for the students, to whom the subject is in their curriculum and then design a corresponding test item for each learning concept. The students were asked to complete a pretest with 20 test items; after completing all course units, the learners were asked to take another 20-item post-test to evaluate their learning achievements. The pattern of questionnaire on the given concept was in the form of: what are the related concepts, examples, applications, sub concepts, etc. The relevant sample items of multiple-choice questions and the user interface of the test environment are shown in Appendix 5.

The experimental procedure comprised the following phases:

**Groups:** A total of 24 undergraduate students were enrolled to participate in the test exam; the students were equally divided into experimental (treatment) group and control group. The control group students were allowed to browse and learn the concepts through traditional approach. The experimental group was allowed to study the stipulated concepts through using the proposed system.

**Pre-test:**

Through the pre-test, the system could obtain information about learners’ prior knowledge levels of the learning concepts as well as the basis of comparison for post-test results.
Post-test:
Learners were allowed for taking post-test when they finished their learning processes and the test results were aimed to compare the learning performance of the two groups of students after taking the course with different learning environment approaches.

Data analysis:
This study analyzed and estimated the performance of system through the Analysis of Covariance between the experimental group and the control group.

The analysis of covariance, often referred to as by its acronym ANCOVA, was performed to test the difference of achievements between the experimental group and the control group. The difference in the experimental group's score from the pre-test to the post-test indicated the change in the value of the dependent variable that could be expected to occur with exposure to the treatment. The descriptive statistics for the analysis is shown in Table 8.4, whereas Table 8.5 presents a summary result of the ANCOVA analysis on the overall post-practice achievement test.

The analysis of covariance results (F=4.77, P=0.038) indicate that the experimental group scored significantly higher than the control group in the post-test and we can acknowledge the same from Figure 8.8 plotted, based on the mean score in Table 8.4. Table 8.5 shows that the research hypothesis holds well with significant level $\alpha=0.05$ and $P = 0.038552< 0.05$. This means that the proposed learning mode provides benefits in terms of learning performance promotion.
Table 8.4 Descriptive statistics of the pretest and posttests

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Post-test scores</th>
<th>Pretest scores</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experimental Group</td>
<td>14</td>
<td>69.78 (13.8315)</td>
<td>55.50 (11.7579)</td>
</tr>
<tr>
<td>Control Group</td>
<td>14</td>
<td>64.78 (10.9881)</td>
<td>59.07 (11.4920)</td>
</tr>
</tbody>
</table>

Table 8.5 Summary of the analysis on the posttest scores

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sum of Squares (SS)</th>
<th>Degrees of Freedom (d.f.)</th>
<th>Mean Squares (MS)</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Group</td>
<td>409.32</td>
<td>1</td>
<td>409.32</td>
<td>4.77</td>
<td>0.038552</td>
</tr>
<tr>
<td>Error</td>
<td>2146.89</td>
<td>25</td>
<td>85.88</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 8.8 Comparison of pre and post test values

8.7.3 Usability Evaluation

The primary purpose of the proposed system is to deliver topics that are concerned with the course curriculum based on the learner’s device context but at the same time the main focus is on enhancing the student learning outcome,
through exposing students to learn presented topics that are conceptually related to learning concept. The added value of the ontology lies in the visualization of the relation among concepts. Thus, students can get better insight into the topic and the related ones.

To elicit the impact and satisfaction level of learners on the proposed system, a questionnaire was designed based on the five Likert-type (1932) scales ranging from 1 to 5 to measure whether or not the features of the proposed learning system satisfies the real requirements of most learners and students assigned one of the values from 1 to 5, with 1 meaning the lowest and 5 denoting the highest. (i.e., poor, average, good, very good, and excellent). The analytical questionnaire was considered as quality metrics to solicit learners’ opinion and to perceive usefulness of the proposed system. The results of the questionnaire analysis were plotted to obtain the graph shown in Figure 8.9 and the mean value was calculated for each category as mentioned in Table 8.6.

Table 8.6 Questionnaire of usefulness evaluation

<table>
<thead>
<tr>
<th>Q.No</th>
<th>Questions</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1</td>
<td>Useful in Reviewing course material</td>
<td>24.2</td>
</tr>
<tr>
<td>Q2</td>
<td>Comfortable to access in mobile environment.</td>
<td>26.4</td>
</tr>
<tr>
<td>Q3</td>
<td>User friendly to search and navigate contents.</td>
<td>21.6</td>
</tr>
<tr>
<td>Q4</td>
<td>Ability to access course material and makes revision of topics easier.</td>
<td>22.8</td>
</tr>
<tr>
<td>Q5</td>
<td>Provides additional information and support to academic course contents.</td>
<td>22.8</td>
</tr>
<tr>
<td>Q6</td>
<td>Satisfaction towards the retrieved contents and learning effect</td>
<td>23.0</td>
</tr>
</tbody>
</table>
The majority of the students that were tested expressed that the system is very useful to navigate to associated topics, and browse documents in this way. The majority of participants endorsed the idea that the proposed mobile-based course learning process could increase student’s interest and engagement in e-learning, as mobile device has been an important asset for every student. However, the heuristic evaluation based on learners’ opinion indicated that the system needed further improvement in delivering more useful resources and needed user friendly interface.

![Figure 8.9 Evaluation on usefulness of proposed system](image)

**Figure 8.9 Evaluation on usefulness of proposed system**

### 8.8 Summary

To solve this context aware learning content delivery problem, the researcher proposed a novel architectural model based on MVC (Model–View–
Controller) design pattern, that was able to perform personalized adaptive delivery of course content according to learner contextual information such as learning style and the characteristics of the learning device using an ontological approach.

This study described the architecture of device independent course-based e-learning application using MVC design pattern and verified the context aware delivery of course contents through incorporating an ontological approach for improving understandability and knowledge level of the e-learner. The prototype of the proposed system was implemented and its usability verified. The user-centered usability evaluation results were more favorable to implement the proposed model in the context aware e-learning environments.