CHAPTER 7

CONTEXT-AWARE CONTENT ADAPTATION

Objective: In this chapter the various possible adaptation approaches, their issues and advantages in e-learning environment are first discussed, and then presented the proposed adaptation approach with its strategies. To attain the desired goal this chapter mainly concentrates on an ontology based context-aware adaptation mechanism based on context description already presented in Section 5.7 of Chapter 5, that is suitable for context aware delivery of learning resources in course based e-learning environment.

7.1 Introduction

The explosion of learning material in the educational domain is leading to informational overload and confusion to access the suitable learning content as per the learner’s expectations. The existing one-size-fit-all approach towards searching and management of learning resource is not compatible in the mobile learning paradigm. At this juncture, the adaptation technique comes into picture that considers the activity, environment, personal details and educational requirements of e-learner which allows us to deliver precise and customized learning material.

In an adaptive e-learning application, the learning content needs to meet the expectations and requirements of the learners. The most widely used adaptation techniques in e-learning environment are referred to the adaptation
that is intended to tailor the learning material to the specific needs of the individual learner. In the context of e-learning environment the term learner model is generally used to mean the special case of user model. Learner model provides an environment to monitor the activities and preferences of e-learner so as to deliver suitable learning material that fulfills the requirements of e-learner.

In the proposed ontology-driven adaptation scenario, the system delivers relevant learning material according to the adaptive rules derived from context ontology that represents learning device, personal details and preferences of the e-learner. The operation model of adaptation mechanism is shown in Figure 7.1.

![Figure 7.1 Adaptation operation model](image)

### 7.2 Study on Adaptation Approaches and Issues

In this section, an attempt is made to investigate and examine different issues that are concerned with adaptation process in e-learning domain.
7.2.1 Locality of Adaptation Mechanism

Adaptation mechanism refers to what is to be adapted before it is sent to the user. In content adaptation, the locality refers to the location where the content adaptation logic is residing. Based on this it can be classified into three categories: client side, server side and proxy side; each of them performs in certain aspects and also may suffer from certain limitations (Md Fudzee & Abawajy, 2008). Adaptation operations can take place in the server, the proxy, the client or combinations. Each design approach has its advantages and drawbacks (Lei & Georganas, 2001).

Client side adaptation:

In client side adaptation, the client device is responsible for taking suitable adaptive functionality according to device features. It is mainly useful for device context adaptation and the adaptation is performed at the client-side through the use of Cascading Style Sheets (CSS). The main drawbacks in client-side adaptation are: it needs additional network bandwidth (Reveiu et al., 2008) and not all browsers support the CSS media types.

Server side adaptation:

In this approach the server is responsible for discovering the suitable content based on the client device capabilities. The main advantage of using server-side adaptation is that the server usually has much more processing power than the client device. So, transcoding skills must be installed at the server to obtain dynamic transformation to other markup languages according to browser capabilities of client device.

CSS: http://www.w3.org/Style.CSS/Overview.en.html
Proxy side adaptation:
The proxy acts as a mediator between client device and content repository and it contains a rich set of transcoders to perform suitable adaptation as per the characteristics of the client device. The proxy based approach permits to transform contents from multiple content repositories. As the adaption logic gets separated from the client and the server, the strategies for content adaptation can be easily upgraded so that this approach becomes more effective than the other ones.

7.2.2 Learner Context Space

In context aware adaptive applications, the behavior of adaptation mechanism depends on learner context model. The adaptation approach can be considered as: development-time perspective and run-time perspective based on learner context space.

Development-time perspective:
In this approach the adaptation logic is directly hard coded in application. As the context space is increasing in e-learning applications this approach is not much efficient.

Run-time perspective:
This is mainly useful for large scale e-learning applications and for large dimension of learner context space. It needs explicit context model, based on which the adaptation behavior changes dynamically.
7.2.3 Adaptation Approaches

The approaches of adaptation mechanism consist of mainly two categories called algorithmic based approach and rule-based approach based on how the adaptation functionality can be obtained.

Algorithmic based approach:
There are different types of adaptation algorithms available in literature. The algorithms proposed by different authors are mainly written through considering the adaptation techniques such as data transcoding, information abstraction and content versioning.

Rule-based approach:
Rule-based systems are simplistic and efficient to implement in knowledge based decision making environments and they are liable for representing the relationships and decision making based on facts. The set of rules and assertions specify how to act. The system examines the conditional statement “IF” and “THEN” to perform necessary operation. The general form of rule statement is: If <premise> then <consequent>.

7.2.4 Adaptation Techniques

The existing learning contents are mainly developed for computer based e-learning so that they need to be modeled for diverse learning devices through different approaches such as Data Transcoding, Information Abstraction and Content Versioning which are the important adaptation techniques that are used mainly in e-learning applications.
Data Transcoding:
It is the process of converting the learning resource format which is suitable to the client device presentation capability. An adaptation module takes care of the conversion of the content from source format to a target format that is compatible to present on target device. The transcoding process is mainly used for image and video file conversion.

Information Abstraction:
The information abstraction consists of compressing the data without any loss of important information (polymorphic presentation) from the perspective of end-user and to make the content deliverable for lower bandwidth requirements and limited display capability. This approach includes the operations such as text summarization, key-frame extraction, etc.

Content Versioning (Maintaining multiple copies of contents):
Creating multiple versions of the authored content which suit different device constraints and maintaining in the learning content resource repository is called content versioning. As proposed by Jalal et al., (2012), the multiple versions of content enable the discovery of the suitable adaptive content that has potentially most useful version for learner-device context. Especially, in device centric content adaption this approach is much efficient.

7.2.5 The Content of the Context Adaptation
In context aware e-learning applications, the learning contents must be adaptable based on device and learner context. Device centric content adaption
and user centric content adaption are the two important approaches based on what context the content is being adapted. As stated by Lum and Lau (2003), the context refers to, who should be considered for the content adaptation and to maximize the adaptation, which is based on the particular user perception and other contextual information such as the client capability, the network connection and the requested content. In general, the content adaptation should be carried out based on priority.

Device centric content adaption:
In device-centric approach, the adaptation is based on the capability of the targeted/client device (Md Fudzee & Abawajy, 2008). The client device characteristics such as hardware and software details are considered to select suitable learning resource that matches the relevant device properties.

User centric content adaption:
In user centric approach, user’s preferences, his interests and surrounding are mainly considered. In e-learning domain the user centric adaption is considered based on user preferences that may be concerned with domain specific (such as subject, topic, etc.) or domain independent (such as orientation, style, learning activities of e-learner, etc.).

**7.3 Towards Proposed Adaptation Approach**

This section describes the content adaptation framework of the proposed system for obtaining context aware web-based learning. Different features of proposed adaptation approach are stated in Table 7.1, based on which the relevant architectural model is designed and implemented.
Table 7.1 Framework of proposed adaptation system

<table>
<thead>
<tr>
<th>Feature</th>
<th>Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Locality of adaptation mechanism.</td>
<td>Server side approach.</td>
</tr>
<tr>
<td>2. Content of the context adaptation.</td>
<td>Device centric and User centric (Device profile and Learner preferences)</td>
</tr>
<tr>
<td>3. Learner context space.</td>
<td>Run-time perspective (Explicit context model).</td>
</tr>
<tr>
<td>4. Usage environment of proposed system.</td>
<td>For course based e-learning.</td>
</tr>
<tr>
<td>5. Approach of adaptation mechanism</td>
<td>An ontology based semantic approach.</td>
</tr>
<tr>
<td>6. The server of content.</td>
<td>Content versioning and ontology based identification.</td>
</tr>
</tbody>
</table>

1. Locality of Adaptation Mechanism: Domain and learner models are connected with the help of adaptive model (Vija, 2012). The adaptive model may be in server, client or in proxy. In the proposed system, the adaptation model is in server side as shown in Figure 7.2. In the server side adaptation approach the server is responsible for identifying the suitable content based on the client device capabilities.

![Figure 7.2 Locality of adaptation mechanism](image)
2. The Content of the Context Adaptation: Device-centric and User-centric are the two content adaption approaches that we can consider based on what context the content is being adapted. In the proposed system, from the device centric perspective we consider the type of device (PC or Mobile) and their software and hardware details obtained through User Agent of HTTP request and from the user (learner) perspective we deal with Resource Type and Learning style of e-learner, obtained from user interface by activity monitoring system.

3. Learner Context Space: The proposed system is designed with an explicit adaptation mechanism which dynamically decides the device type and learning context of the learner.

4. System Usage Environment: The system is designed for the purpose of context aware adaptive delivery of learning resources and it is mainly developed for course based e-learning environment where the course contents are being organized and managed with adaptation oriented resource description ontology so as to deliver the contents based on device capabilities and learner preferences. It facilitates better understandability and cognitive skills of the learner.

5. Adaptation Mechanism: The adaptation mechanism in the system is based on device context and learning style of e-learner. The proposed system is not an adapted system but it is the combination of adaptive system (automatic finding of device context, through analyzing User Agent profile received from HTTP request) and adaptable system (learner needs to enter learning style context explicitly).
6. The Server of Content: The content server maintains separate versions of resources for mobile and PC clients. The learning contents are authored for two different categories of clients. The suitable content is identified using resource description ontological metadata as per the context of the learner.

7.3.1 Stages in Proposed Adaptation Process

Adapting learning content to the needs of e-learner requires matching of the learner context with the knowledge-based (ontology-based) representation of learning content. The adaption mechanism needs to develop adaptation rules for learner needs based on information (learner context) such as preferences, activity and learning device capabilities of the e-learner. As shown in Figure 7.3 the semantic based adaptive rules are derived from formally represented ontology of the learner context. The proposed adaptation strategy is implemented in a separate adaptation layer, in which the learning activity and the preferences of the learner get transformed into respective adaptive actions.

Figure 7.3 Different stages in adaptation process

7.3.2 The Adaptation Strategies

In e-learning environments, we may provide learning contents not only adaptive to the learner but also adaptive to the learning device. The context in the learning environment may vary based on learning device, domain type, learner preferences, etc., so the incorporation of contextual knowledge in
adaptive mechanism will make e-learning systems more effective. The adaptive process based on context creates suitable content for learners according to contextual and situational data.

The adaptation mechanism supports the adaptive delivery of the learning material based on the learner’s context to satisfy the needs of the e-learner. The proposed approach will consider the learning context such as 1) Device type (computer, mobile device, etc.), 2) Learning approach (style, preferences, etc.) and 3) Domain specific preferences (subject, concept, etc.).

### 7.3.3 Dimensions of Adaptation Approach

The proposed adaptation approach is the cascading of two techniques: the learner context information is represented through an ontological approach, and then the suitable adaptive rules are extracted through considering the semantic relationships behind a learner’s context information. As shown in Figure 7.4 the dimensions in the proposed adaptation mechanism consist of device context (device information) and learner context (resource type and learning style).

![Figure 7.4 Dimensions in adaptation mechanism](image)
7.4 Context Aware Adaptation Mechanism

In this section, mechanism for adaptive delivery of learning content based on learner context model is described. In course based e-learning environments, the course contents are hierarchically structured; they include some subject domain, concepts, sub concepts, applications, examples, etc. The logical notion of our proposed adaptation approach includes two phases, at the content level and at the presentation level.

Content level:
At the content level, the course contents are customized to match learning device capabilities and learner preferences specified by the learner context model.

Presentation level:
The second phase attempts to recommend the related concepts, prior concepts and sub concepts of the current learning concept, through the customization of the link structure of contents according to the presentation model.

The context-specific knowledge is represented with decision rules, to deliver suitable content based on learner context. The knowledge base is composed of production (normative) rules which include learner preference rules and device capability rules. The appropriate adaptive rules are extracted from rule database, taking into account the reasons behind a learner activity. Figure 7.5 represents the general architecture of the system that is able to capture various contextual parameters as per the dimensions of the proposed adaptation.
mechanism. The context profile of the learner includes device characteristics and user preferences to generate a set of adaptation specifications.

Here, the researcher would like to mention different normative rules that comply with the criteria of conceptual relations in the learner context model. Normative rules constrain the application logic to ensure the consistency and the integrity of the data and the application (Soylu et al., 2011). The normative rules are built on top of context model (i.e., rules use the vocabulary specified in the ontology). The focus is on learning device type and preferences of the learner as adaptive dimensions for developing the rules. The context aware adaptation mechanism is expressed in Semantic Web Rule Language (SWRL) to obtain an adaptive course content delivery process. The reason behind choosing SWRL is that, it is W3C recommendation for the representation of rules as well as logic
and it is to increase interoperability, reusability and is compatible with OWL which has been used for context ontology modeling. The adaptive SWRL rules mentioned in Table 7.2 are developed based on context ontology that is formally represented in Table 5.4 of Section 5.7 of Chapter 5.

Table 7.2 SWRL adaptation rules based on context ontology

<table>
<thead>
<tr>
<th>Context Type</th>
<th>SWRL Rules</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Device Context</strong></td>
<td><strong>Context Type</strong></td>
</tr>
<tr>
<td></td>
<td>Student (?St) ∧ hasDevice (?St, ?Dv) ∧ Device (?Dv)</td>
</tr>
<tr>
<td></td>
<td>(Device (?Dv) ∧ ofType (?Dv, Dt) ∧ Device-Type (?Dt))</td>
</tr>
<tr>
<td></td>
<td>(Device (?Dv) ∧ hasBrowser (?Dv, Bt) ∧ Browser-Type (?Bt))</td>
</tr>
<tr>
<td></td>
<td>(Device (?Dv) ∧ hasScreenSize (?Dv, Ss) ∧ ScreenSize (?Ss))</td>
</tr>
<tr>
<td><strong>Domain Specific Learner Context</strong></td>
<td>(Student (?St) ∧ isCoursing (?St, ?Ct) ∧ Course (?Ct))</td>
</tr>
<tr>
<td></td>
<td>(Course (?Ct) ∧ hasTopic (?Ct, Tp) ∧ Topic (?Tp))</td>
</tr>
<tr>
<td></td>
<td>(Preference (?Pr) ∧ ofLearningOrientation (?Pr, Lo) ∧ LearningOrientation (?Lo))</td>
</tr>
<tr>
<td><strong>Domain Independent Learner Context</strong></td>
<td>(Student (?St) ∧ hasPreference (?St, ?Pr) ∧ Preference (?Pr))</td>
</tr>
<tr>
<td></td>
<td>(Preference (?Pr) ∧ ofMediaType (?Pr, Mt) ∧ Media-Type (?Mt))</td>
</tr>
<tr>
<td></td>
<td>(Preference (?Pr) ∧ ofLanguage (?Pr, Ln) ∧ Language (?Ln))</td>
</tr>
</tbody>
</table>

As mentioned in “Section 5.7” the device context (DC) and learner preferences context (PC) are the two sets of parameters that are considered to obtain context aware adaptive functionality. The context aware adaptation mechanism takes two contextual dimensions DC and PC as arguments and delivers the matching learning resource to the learner. The adaptive rules in SWRL format, mentioned in Table 7.2 are responsible for adaptation. Here is an example scenario:
If student “X” doing “Computer Science” course selects material in the video format of “Graphics” subject, then the context can be as follows:

Context of Student X =
{
(Student . X , isCoursing , Course . Computer Science)
(Course . Computer Science , hasTopic , Topic . Graphics)
(Student . X , hasDevice , Device . PC)
(Student . X , hasPreference , Preference)
(Preference , ofMediaType , Media-Type . Video)
}

### 7.5 Steps in Adaptation Process

The proposed context aware adaptation methodology is mainly concerned with course based e-learning environment. The behavior of the context aware adaptive delivery process consists of the following steps and is depicted in Figure 7.6.

1. First, the registration process has to be completed by the learner so that the learner is allotted with learner-id which will be used to identify the user’s primary details such as Language, Standard, Qualification, etc.

2. After the completion of learner’s login process, the system automatically detects the type of device (such as mobile or PC) and its characteristics, through evaluating the User Agent of HTTP request\(^{39}\).

\(^{39}\)User Agent of HTTP request: http://www.httpuseragent.com/
3. Before starting to learn particular course contents, the learner needs to enter the preferences such as file format and orientation of learning (such as Application, Case-study, Examples, etc.).

4. The device centric and learner centric contextual information is stored under context-id of relevant learner-id.

5. Based on contextual information and using CALRO ontological metadata (of resource information) the adaptation process selects learning resources using query statements that may correspond to SQL statements or SPRAQL statements (if contents are managed using Ontology).

Figure 7.6 Adaptive delivery process
7.6 Summary

The ontological framework based on three different dimensions of contextual information may help context model designers of device independent adaptive e-learning system. The ontological representation of learner model has given the full expression to understand the relations among various requirements and characteristics of the e-learner. Various possible adaptation approaches and their respective issues have been discussed besides proposing the context aware adaptation mechanism based on rules that are derived from context ontology.
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.