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Content Adaptation Approach in Context-aware Delivery of Learning Material

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Abstract: The existing search techniques and digital learning resources are good enough for computer based e-learning. The recent trend of learning styles and diversity of digital learning devices created many challenges to learning content delivery, presentation and management system. The diversity in digital learning devices and different types of learning resources have raised the issues to discover and present the most suitable version of a learning resources that are compatible for the concerned learning device-context and learning style requirements of e-learner. Our goal is to develop semantic rule based adaptive mechanism for device independent context aware course based e-learning system. This paper presents an epigrammatic study on various approaches and issues in different stages of content adaptation process that are applicable for e-learning domain and developing an ontological description based on three different dimensions of contextual information from which the concerned semantic based adaptive rules are derived. Finally, the proposed adaptation mechanism and its advantages are discussed along with the concerned architectural model.

Key words: Ontological; Content Adaptation; Context-aware; e-learning; Dimensions.

INTRODUCTION

The explosion of learning material in 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 in to picture, that consider the activity, environment, personal details and educational requirements of e-learner, which allows us to deliver précised 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 learning material to the specific needs of individual learner.

In the context of e-learning environment the term learner model is generally used to refer 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 fulfill 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 e-learner.

The paper is organized as follows: after studying the various possible adaptation approaches, their issues and advantages in learning environment, first, we present the proposed adaptation approach and its strategies. Then we deal with an ontology based description of context and context-aware adaptation mechanism that is suitable for context aware delivery of learning resources in course based e-learning environment.

Related Work:

Ontologies have proven their success in many application domains like Bio-informatics and E-commerce. As we stated in (KallaMadhuSudhana, *et al.*, 2013) the ontologies are being used in educational domain for personalization, adaptation and recommendation of learning material.

A well-defined context model is an important key to access the context information of any context-aware system (Strang, T., &Linnhoff-Popien, C, 2004, September). This paper introduces an ontology based learner context model to describe the semantic relationships between context entities.

The adaptation logic which is derived from context model is used to perform adaptive delivery of learning contents as per the learner context. The adaptation logic selects suitable content based on resource description metadata. Schmidt (Schmidt, A, 2005, October) noted that, the contextual metadata needs to be provided along with the learning resources to allow efficient filtering based on learner context.

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Park, S (Park, S., & Lee, J. K, 2007) proposed a procedure of rule identification using "OntoRule", an ontology-based rule identification procedure through eXtensible Rule Markup Language (XRML) approach and discussed several issues in using ontology in rule identification. Bontchev (Bontchev, B., &Vassileva, D, 2009, July) proposed the construction of adaptation engine for rule-driven approach that allows separation of adaptive rules from business logic.

Adaptive delivery based on learner context model allows improved readability and understandability of learner. Shute (Shute, V., &Towle, B, 2003) noted that, in the context of adaptive e-learning the adaptation decision relates to customizing the content as per the learner context model.

The hierarchical content presentation helps learner to navigate through related concepts of current learning concept. "AdaptWeb" (de Freitas, V., et al., 2002) project offers adaptive content presentation of course contents associated to specific course, this adaptation approach is based on particular student profile.

Adaptation Approaches and Issues:

Here, we target addressing different issues such as types, location and techniques concerned to adaptation process in e-learning domain.

***Locality of Adaptation Mechanism*:**

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 as: client side, server side and proxy side (MdFudzee, M. F., & Abawajy, J., 2008, November).

- *Client side adaptation*: In client side adaptation, the client device is responsible to take 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, A., et al., 2008, July) 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.
- *Proxy side adaptation*: The proxy acts as mediator between client device and content repository and it contains a rich set of transcoders to perform suitable adaptation as per the characteristics of client device. The proxy based approach permits to transform contents from multiple content repositories. As the adaption logic get separated from client and server, the strategies for content adaptation can be easily upgraded, so that, this approach is most effective than the other ones.

Learner Context Space:

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

- *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.

Adaptation Mechanism:

The approaches of adaptation mechanism consist of mainly two categories as 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 technique such as data transcoding, information abstraction and content versioning.
- *The 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 condition under "IF" statement of all the rules set; if the condition of any rule is satisfied then the operation under the "THEN" statement is performed. The general form of rule statement is: If <premise> then <consequent>.

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 in e-learning applications.

- *Data Transcoding*: is the process of converting the learning resource format that is suitable according to client device presentation capability. An adaptation module takes care of the conversion of 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 learning 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 in (Jalal, A., et al., 2012) the multiple versions of content, enables the discovery of the right adaptive content that has potentially most useful version for learner-device context. Especially, in device centric content adaption this approach is much efficient.

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 (Lum, W. Y., & Lau, F. C, 2003), the context is referred as, who should be considered for the content adaptation and to maximize the adaptation.

- *Device centric content adaption*: In device-centric approach, the adaptation is based on the capability of the targeted/client device (MdFudzee, M. F., &Abawajy, J, 2008, November). The client device characteristics such as hardware and software details are considered to select suitable learning resource that matches the concerned device properties.
- *User centric content adaption*: The user centric adaption is considered based on user preferences that may be concerned to domain specific (such as subject, topic etc.) or domain independent (such as orientation, style, learning activities of e-learner, etc.).

Towards the Proposed Adaptation:

Here, our goal is to develop an ontology based context model comprised of the device and learner context characteristics. The proposed mechanism uses ontology, based on which the production rules are derived to obtain the specified adaptation functionality. The operation model of the adaptation mechanism is as shown in Figure 1.

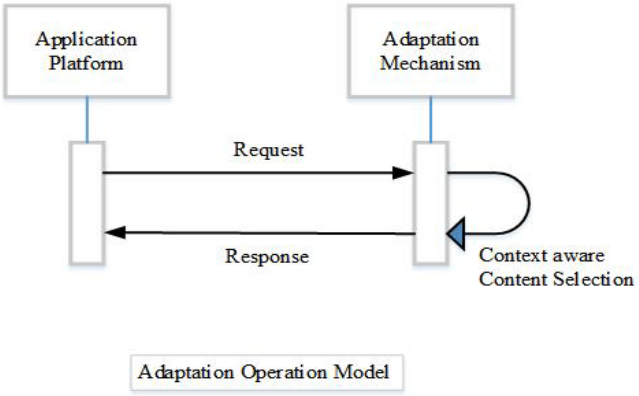

Fig. 1: Adaptation operation model.

Stages in Proposed Adaptation Process:

Adapting learning content to the needs of e-learner requires matching of learner requirements 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 e-learner.

As shown in Figure 2 the semantic based adaptive rules are derived from formally represented ontology of learner context. So that the content selection rules are derived from the learner's learning activity space, which represents the learner preferences and requirements relating to the learning resources description model.

The proposed adaptation strategy is implemented in a separate adaptation layer, in which the user learning activity and feedback gets transformed in to respective adaptive actions.

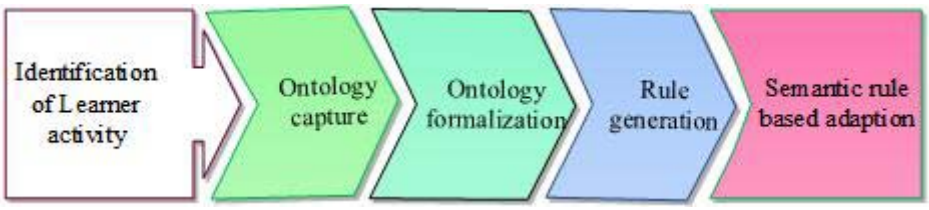

Fig. 2: Different stages in adaptation process.

The Adaptation Strategies:

In e-learning environments, we may provide learning contents not only adaptive to learner but also adaptive to learning device. The context in 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 learning material based on learner's context to satisfy the needs of e-learner. The proposed approach will consider 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.).

The Adaptation Approach:

The adaptation approach proposed in this paper 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 3 the dimensions in the proposed adaptation mechanism consist of device context (device information) and learner context (resource type and learning style).

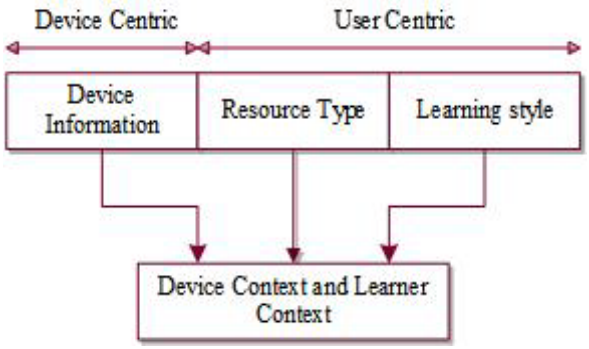

Fig. 3: Dimensions in adaptation mechanism.

Semantic-Based Description of Context:

As we mentioned in (Sudhana, K. M., et al., 2012) the ontological representation of learner model in e-learning domain increases the accessibility and the reusability of the learning material. Here, the contextual entities of learning environment are described using an ontological approach, from which the concerned adaptation logic is derived. The purpose of the ontology based context model is to formalize the structured contextual entities by making use of the ontological methodology to define the concepts and relationships of the context elements (Qin, W., et al., 2007).

To model the real-world applications it needs complex rules, so meaning captured into ontology for the problem domain becomes very helpful for rule extractions when building complex systems (Shih, W. C., & Tseng, S. S, 2009). The ontological approach is a suitable means for representing learner contextual information. Based on learner context ontology the production rules are derived and stored in knowledge base.

The semantic technology and ontological approach are emerging as promising approaches to leverage the retrieval and presentation of dynamic context (Roy, N., et al., 2010). The semantic-based description of learner context information is being described based on conceptual relations (Domain, Range and Relation) of three different contextual dimensions are as shown in Table1.

The set of contextual elements in learning environment can be divided in to two classes as device context and learner context. Again the learner context has two parts, the domain independent and domain specific. The domain independent part defines characteristics of learner such as learning style and preferences. The domain

specific part reflects the characteristics of learner for a particular domain and refers to the concepts from the respective domain model.
The formal description of learner context ontology can be defined as shown in Table 2.

Table 1: Context categories and semantic relations.

Context Category	Domain	Relation	Range	Example
Device Context	Student	*hasDevice*	Device	
	Device	*ofType*	Device-Type	Mobile
	Device	*hasBrowser*	Browser-Type	Fire Fox
	Device	*hasScreenSize*	ScreenSize	Size
Domain Independent Learner Context	Student	*hasPreference*	Preference	
	Preference	*ofMediaType*	Media-Type	Video
	Preference	*ofLanguage*	Language	English
	Preference	*OfLearningOrientation*	Learning-Orientation	Case Study
Domain Specific Learner Context	Student	*isCoursing*	Course	Computer Science
	Course	*hasSubject*	Subject	Data Structures

Table 2: Formal description of context ontology.

Learner Context ontology= {Device, Learning Preferences}
Device Profile = {Type, Hardware, Software}
Type= {PC, Mobile}
Hardware= {Model, Screen Size}
Software= {Protocol, Browser, OS, Image Format}
Learning Preferences = {Domain Specific, Domain Independent}
Domain Specific= {Subject, Concept, Sub Concepts, Prior Concepts, Related Concepts}
Domain Independent= {Media Preference, Learning Orientation, Language}
Resource Type= {Audio, Video, Interactive File, Text}
Learning Orientation= {Case study, Example Oriented, Application Oriented}
Language= {English, French, etc}

Context-Aware Adaptation Mechanism:

In this section, we describe mechanism for adaptive delivery of learning content based on learner context model.

In course based e-learning environments, the course contents are hierarchically structured; it includes 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 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 4 shows the general architecture of the system that is able to capture various contextual parameters as per the dimensions of proposed adaptation mechanism. The context profile of learner includes device characteristics and user preferences to generate a set of adaptation specifications.

Here, we 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 integrity of the data and the application (Soylu, A., et al., 2011). The normative rules are built on top of context model (i.e., rules use the vocabulary specified in the ontology).

We focused in particular on learning device type and preferences of 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 Web Ontology Language (OWL) which we used for context ontology modeling.

The adaptive SWRL rules shown in Table 3, that are developed based on context ontology that is formally represented in previous section and the corresponding Table 1 shows context related properties along with their domains and ranges.

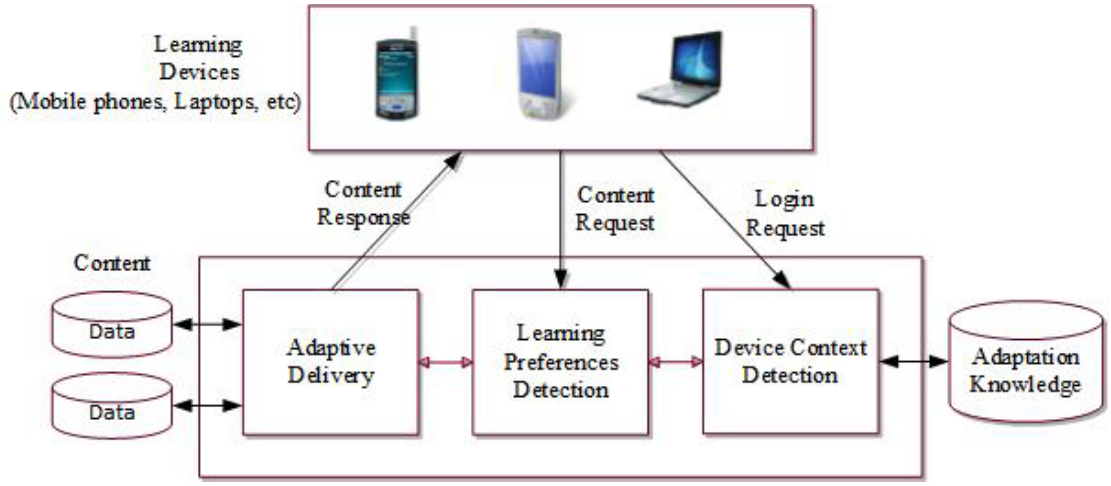

Fig. 4: General architecture of proposed approach.

Table 3: SWRL adaptation rules based on context ontology.

Context Type	SWRL Rules
Device Context	Student (?St) ∧ hasDevice (?St, ?Dv) ∧ Device (?Dv) (Device (?Dv) ∧ ofType (?Dv, Dt) ∧ Device-Type (?Dt)) (Device (?Dv) ∧ hasBrowser (?Dv, Bt) ∧ Browser-Type (?Bt)) (Device (?Dv) ∧ hasScreenSize (?Dv, Ss) ∧ScreenSize (?Ss))
Domain Independent Learner Context	(Student (?St) ∧ hasPreference (?St, ?Pr) ∧ Preference (?Pr)) (Preference (?Pr) ∧ ofMediaType (?Pr, Mt) ∧ Media-Type (?Mt)) (Preference (?Pr) ∧ ofLanguage (?Pr, Ln) ∧ Language (?Ln)) (Preference (?Pr) ∧ ofLearningOrientaion (?Pr, Lo) ∧ LarningOrientation (?Lo)
Domain Specific Learner Context	(Student (?St) ∧ isCoursing (?St, ?Ct) ∧ Course-Type (?Ct)) (Course-Type (?Ct) ∧ hasSubject (?Ct, Sub) ∧ Subject (?Sub)

As mentioned in Figure 3 the device context (device features) and learner context (learner preferences) are the two sets of parameters that are considered to obtain context aware adaptive functionality.

Device Context (DC) = {dc1, dc2, dc3... dcn}

Where

dci is one of all features of learner device i; n is total number of device features.

Learner Context (LC) = {Language preference, Content Type preference, Content Format preference}

Where

Language preference = English, Chinese, etc.

Content Type preference = Example, Application, Case Study, etc.

Content Format preference = Text, Image, Audio, Video, Webpage, etc.

Then the Context Profile is denoted as a 3-tuple: Context Profile (CP) = <I, DC, LC >

Where

I: denotes the learner's context identity;

DC: denotes the receiving device context;

LC: denotes the learner context;

The context aware adaptation mechanism takes two contextual dimensions DC and LC as arguments and delivers the matching learning resource to learner.

The adaptive rule in SWRL format, mentioned in Table 3 is responsible for adaptation. Here is an example scenario:

If student "X" selects material in video format of "Graphics" subject then the context can be as follows:

Context1= {(Student . X , isCoursing , Course . Computer Science)
(Course . Computer Science , hasSubject , Subject . Graphics) (Student . X , hasDevice , Device . PC)
(Student.X , hasPreference , Prefernce) (Prefernce . Media , ofMediaType , Media.Video) }

Proposed Approach and its Advantages:

The proposed context aware adaptation methodology is mainly concerned to course based e-learning environment and it is composed of following steps:

(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 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 (UAProf Version 20, 2001) request.
(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 concerned learner-ID and translated into a corresponding set of adaptation statements.
(5) As mentioned earlier, the adaptation process selects learning resources at content level and at the presentation level. The learning resources that are stored using metadata file are selected based on learner context rules which are mentioned in Table 3. Secondly, presentation level helps learner to navigate through presentation model to select semantically related concepts of current learning topic.

Adaptation statements may correspond to, SQL statements or SPRAQL (SPARQL Protocol and RDF Query Language) statements (if contents are managed using Ontology) at the content layer. The adaptation is achieved by means of special logical rules to meet the requirements of adaptation as per the given context profile.

When dealing with learner's activity information it is always a challenge to describe facts of learner's learning style and their interrelationships. An ontological approach seem to be well suited to represent the concepts of learning style and thereby deriving suitable rules of learning style to take adaptive decisions.
(1) We chose ontology for our activity modeling: as it can be formally represented with W3C recommended semantic based languages like RDF and OWL.
(2) Rules and ontologies can be embedded in a common logic language.
(3) The classes and properties of the ontology can be defined in rules.

Discussion:

Through representing learner activities and preferences in an ontological format, we can take advantage of ontology representation languages such as RDF/OWL to define the learner characteristics and for preserving the semantics of learner context from which the concerned adaptation logic is derived.

The ontological representation of learner model has given the full expression to understand the relations among various requirements and characteristics of e-learner. As the ontologies expression ability is insufficient to provide efficient adaptive delivery of learning material, we used the semantic knowledge based rules that are derived from an ontological learner context model to enhance the efficiency in adaption process.

Conclusion and Future Work:

In this paper various possible adaptation approaches and concerned issues have been studied and then, we proposed the context aware adaptation mechanism based on rules derived from ontology for context aware course based e-learning environments.

The ontological framework based on three different dimensions of contextual information may help context model designers of device independent adaptive e-learning system. Our future research will focus on developing adaptable resource description ontology that covers different aspects of context adaptation and implementing the proposed device independent course based e-learning system.

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