COMET: Context Ontology For Mobile Education Technology

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Abstract. The use of mobile devices is increasingly prevalent in education. These devices provide the convenience of supporting access to learning anytime, anywhere. Further, mobile learning provides opportunities to tailor the learning experience to dynamically changing contexts. Major challenges for constructing context-aware models to support this kind of learning include defining the contextual information and adapting to dynamic changes. Ontology-based context models exhibit features such as expressiveness, extensibility, ease of sharing and reuse, and logic reasoning support, and thus show promise in this area. In this paper, we propose COMET (Context Ontology for Mobile Education Technology) in order to provide a semantically rich model for mobile learning. More specifically, we have demonstrated an example application to show how we can retrieve contextual data from different participating entities within the ontology by using their semantic understanding.

Keywords: Mobile learning, Context, Ontologies.

1 Introduction

The last decade has witnessed a spectacular evolution in mobile technologies, and these technologies have increasingly been used in education. Mobile devices can play an important role in creating more individualized and collaborative learning environments, because their flexibility and portability allow learning on-the-fly [1], "anywhere or anytime". Further, mobile learning provides opportunities to tailor the learning experience to dynamically changing contexts.

The development of context-aware applications deals with a number of technological challenges and requires the existence of a suitable contextual model that can be represented and understood between different entities, such as devices and applications, using a common semantic understanding [2]. In the education field, context-aware learning is generally applied to content adaptation and device-independent content presentation to serve different learners and their situated learning environments [3]. Some other context-aware systems have been developed in terms of device adaptability, such as tourist information being received by different types of devices, described generically in [4] and specifically for the Innsbruck.mobile application [5] in which an adaptation framework is used to adapt the application to all possible access devices (e.g. laptop, Smartphone etc.). In both applications, adaptation is used in a single direction, from resource to device, as contents are adapted according to different device types. However, such uni-directional transformations do not fully explore the potential of semantic representations, and the application of context-aware systems that adapt from multiple perspectives has been sparsely explored. For comprehensive adaptivity support, we need an approach which can deliver adaptive contents from any platform in any format to any device through any network at any time anywhere [6]. This is only possible when the participating entities in the context model, such as applications and devices, have rich semantic understandings between each other.

In recent years, ontologies have emerged as one of the most popular and widely accepted tools for modelling contextual information in mobile computing domains [7]. Ontology-based context models exhibit features such as expressiveness, extensibility, ease of sharing and reuse, and logic reasoning support [8]. Several context ontologies have been proposed in the literature but thus far they have not been able to capture all the relevant information needed for technology enhanced mobile education. Therefore, we are addressing the following research questions in this paper: What would be the components of a comprehensive context ontology for mobile education technology? And how can an ontology based context model retrieve contextual data between different entities?

In this paper, we present our context ontology COMET, which extends previous context ontologies described in the literature including CONON [2], Feng et al., [9], Preuveneers et al., [10] CALA-ONT [11] and MeCoCo [12]. COMET is based on three key concepts; learner, environment and activity. As an example of applying multiple perspectives to querying our ontology, we consider two key scenarios; one in which an educator wishes to identify suitable mobile applications for their students according to the availability of particular mobile devices, and another in which they wish to identify devices that can run a chosen application. Other related scenarios are also considered. To test the utility of our ontology we built a prototype ontology driven web application that demonstrates information retrieval using queries from multiple perspectives.

The remainder of this paper is structured as follows. In section 2, the basic concepts of COMET are discussed. Section 3 suggests other key concepts in COMET which derive from previous context ontologies. A subset of the ontology is described in section 4 to show how entities are defined and inter-related. In section 5, different types of queries are used to demonstrate the extraction of specific information. Finally, section 6 contains concluding remarks and discusses some future research directions.

2 Context Modelling

Context can be viewed from different perspectives. In particular, three general approaches have been used to categorize context i.e. operation based, concept based and domain based [3]. Operation based context relates to how context information is acquired from sensors or other devices, whereas domain based context defines how context information is used in a particular domain. Concept-based categorization describes two types of contexts in a broader perspective: user-centric context and environmental context. There is no definite agreement about what should be modelled in the area of context but most previous work on context in mobile computing focuses on a common core that includes environment and human dimensions [13], which follow concept-based categorization.

For the mobile learning domain, Parsons et al. [14] described the design of applications from four perspectives: the mobile environment, the learning context, the learning experience, and the learning objectives. We are focusing on one of these important aspects: the learning context, which is defined as "the situation under which a learning activity happens and this situation includes the learner and his/her surrounding environment" [3]. Three important aspects are covered in above definition; learner, environment and activity. In addition, CONON [2] also suggested activity as a separate dimension of context which is lacking in concept-based categorization. Therefore, we have extended our categorization to include three components as shown in fig. 1.

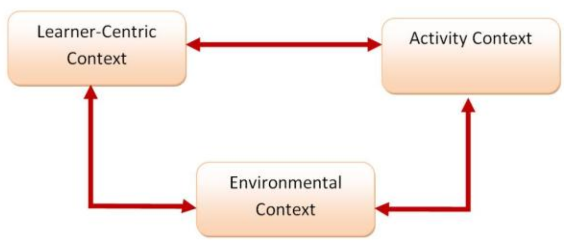

Fig. 1. The three basic components in our learning context model

3 Classifying Contextual Information

Ontology-based context models provide formal notation, which allows semantically consistent inference, and also assures a shared and reusable representation of the contextual information among different entities [4]. Several context ontologies have been discussed in the literature but none of them are able to fully define a context ontology for mobile education technology. However, we have considered those previous ontologies in defining our own context ontology, COMET. The main concepts of our ontology are described in the following subsections:

3.1 Learner-centric Context

The *Learner-centric Context* is categorized into four main entities: Profile, Preference, Physiological and Cognitive. Profile is used to handle the learner's personal information such as name, address etc. The Preference context contains information about the learner's preferences including learning style and learner's intention. Physiological and Cognitive states are related to the learner's physical and cognitive characteristics [9].

3.2 Environmental Context

The *Environmental Context* is discussed in most of the other context ontologies; Feng et al. [9] categorized environmental context into three environments, Wang et al. [2] divided it into two parts while Preuveneers et al. [10] mentioned one aspect of an environment only. However, we have followed MeCoCo [12] in describing our environment context. It has four distinct parts:

- **Physical Environment** which gives information on the learner's spatio-temporal and environmental condition where learning activities are being carried out.
- **Social Environment** which encompasses other learners who are physically or logically close to the current learner.
- **Virtual Environment** which specifies information about the indirect view of a physical real-world environment whose elements are augmented by virtual computer-generated data such as sound or graphics.
- **Computational Environment** which describes information about devices and applications used by the learners.

3.3 Activity Context

The *Activity Context* is used to describe information about the users' task, goals and availability [12]. We have defined activity context into two basic activities: Other Activity and Learning Activity as suggested by [11]. Other Activity comprises activities like presentations, quizzes or discussions while Learning Activity consists of mobile learning activities defined by [15], which are as follows:

- **Physical exercise games** activities can be designed to allow learners to explore the effect of their actions on different abstract representations, to support conceptual understanding by engaging themselves into physical activities.
- **Participatory simulations** activities can be used to enable learners to act out individual roles and see the effects of their physical actions in relation to other learner's actions on a combined digital display.
- **Field trips and visits** activities can be designed to enable learners to collect data from the environment and view it as part of a larger scientific pattern.
- **Content creation** activities can be designed to be more meaningful, enabling learners to construct richer and more complex narratives.

4 Usage Scenario

In this section, we present the use of our COMET ontology. The implementation of this application has allowed us to evaluate the semantic understanding between different entities of the model. In our reference scenario an educator wants her students to interact with one or more currently available mobile applications. For that reason, she needs to know what types of platform are required for specific applications or vice versa. This example demonstrates how an ontology needs to be able to be queried from multiple perspectives and across multiple entities. For instance, OOKL[1] (Application) requires the iOS (iPhone Operating System), platform to run. Similarly, only Windows Mobile (Platform) can support mscape[2].

As a proof of concept, we have chosen 11 recent mobile applications and around 60 mobile devices and their supported versions with some other related information to show how they are semantically inter-related. These are represented in our ontology (fig. 2).

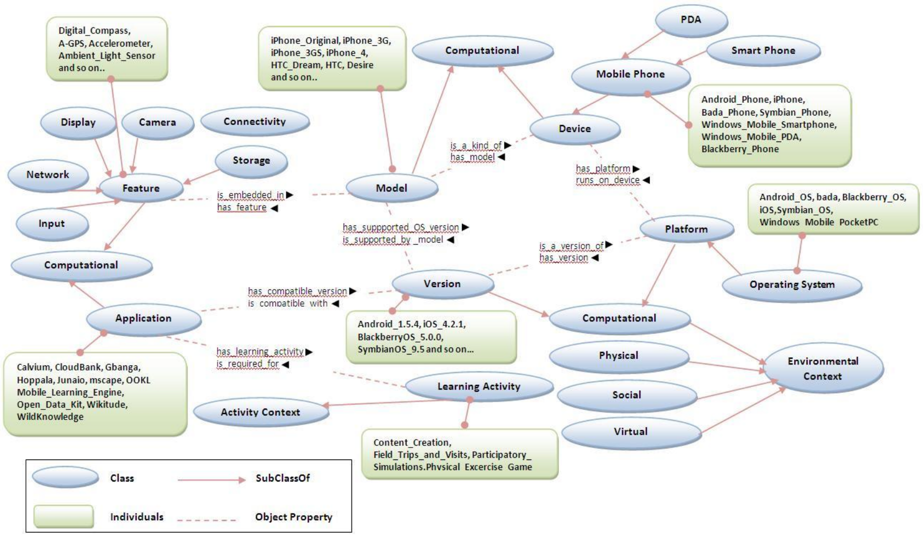

Fig. 2. Excerpts from our context ontology - COMET

5 Semantic Information Extraction

In this section, we describe our use of queries within a web architecture [16] for demonstrating relevant information retrieval using COMET. In this architecture, a Java platform is used for back-end to access our context ontology which is provided through Jena[3] and SPARQL[4]. Jena is an open source Java API for building semantic web applications and SPARQL is a query language for ontologies defined in OWL (Web Ontology Language). In this particular example, we show how relevant information is

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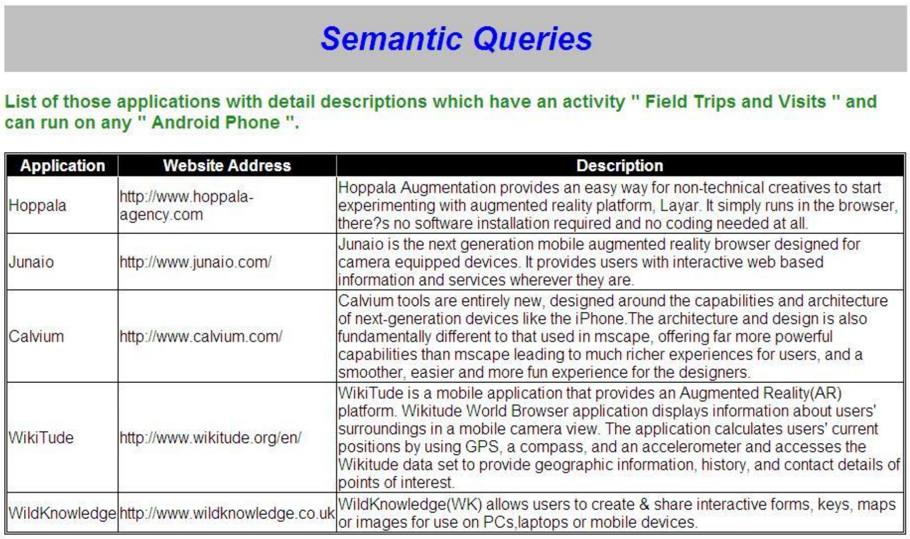
[1] http://www.ooklnet.com/web/index.php
[2] http://www.hpl.hp.com/mediascapes/
[3] http://jena.sourceforge.net/)
[4] http://www.w3.org/TR/rdf-sparql-query/

extracted from our ontology by using SPARQL queries as shown in Table 1. We also show an example of one of the results of these queries as presented in our web application (fig. 3). This application shows how ontology-based context models are semantically rich and can extract specific data by using semantic relationships between entities.

Table 1. User-defined SPARQL queries with their results

Queries	SPARQL Syntax	Result
a) List of models which can support **Hoppala**	SELECT DISTINCT ?Model WHERE { ?Model :has_supported_OS_version ?Version. ?Version :is_compatible_with ?Application . FILTER(?Application = < http://www.massey.ac.nz/context.owl#Hoppala>)}	iPhoneOriginal,iPhone_3G, iPhone_3GS,iPhone_4,Nexus_ One, Motoralla_Droid_Eris, HTC_Dream,HTC_Desire, HTC_Magic,HTC_Hero, HTC_Tattoo,HTC_Droid_Eris, Red_Bull_Mobile_RBM2, Samsung i7500
b) List of applications which can run on **iPhone-4**	SELECT DISTINCT ?Application WHERE { ?Application :has_compatible_version ?Version. ?Version :is_supported_by_model ?Model . FILTER(?Model = < http://www.massey.ac.nz/context.owl#iPhone_4 >) }	Junaio, Hoppala, Gbanga, OOKL, Calvium
c) List of models with **Digital Compass** supported by **Symbian 9.5** and **WikiTude**	SELECT DISTINCT ?Model WHERE { ?Model :has_feature ?Feature. FILTER (?Feature = < http://www.massey.ac.nz/context.owl#Digital_Compass >)?Model :has_supported_OS_version ?Version. FILTER(?Version = < http://www.massey.ac.nz/context.owl#symbian_9.5 >)?Version: is_compatible_with? Application. FILTER(?Application = < http://www.massey.ac.nz/context.owl#WikiTude>)}	Nokia_C6-01 Nokia_C7-00 Nokia_E7-00 Nokia_N8_00

d) List of those applications with detail descriptions which have an activity **Field Trips and Visits** and can run on any **Android Phone**	SELECT DISTINCT ?Application ?website ?about
	WHERE {
	?Application :website_link ?website.
	?Application :description ?about.
	?Application: has_learning_activity ?Learning_Activity.
	FILTER(?Learning_Activity = <
	http://www.massey.ac.nz/context.owl#Field_Trips_and_
	Visits >) ?Application :has_compatible_version
	? Version .
	?Version :is_a_version_of ?Platform.
	?Platform :runs_on_device ?Device.
	FILTER(?Device = <
	http://www.massey.ac.nz/context.owl#Android_Phone>)
	}
		see figure .3



Semantic Queries

List of those applications with detail descriptions which have an activity " Field Trips and Visits " and can run on any " Android Phone ".

Application	Website Address	Description
Hoppala	http://www.hoppala-agency.com	Hoppala Augmentation provides an easy way for non-technical creatives to start experimenting with augmented reality platform, Layar. It simply runs in the browser, there?s no software installation required and no coding needed at all.
Junaio	http://www.junaio.com/	Junaio is the next generation mobile augmented reality browser designed for camera equipped devices. It provides users with interactive web based information and services wherever they are.
Calvium	http://www.calvium.com/	Calvium tools are entirely new, designed around the capabilities and architecture of next-generation devices like the iPhone.The architecture and design is also fundamentally different to that used in mscape, offering far more powerful capabilities than mscape leading to much richer experiences for users, and a smoother, easier and more fun experience for the designers.
WikiTude	http://www.wikitude.org/en/	WikiTude is a mobile application that provides an Augmented Reality(AR) platform. Wikitude World Browser application displays information about users' surroundings in a mobile camera view. The application calculates users' current positions by using GPS, a compass, and an accelerometer and accesses the Wikitude data set to provide geographic information, history, and contact details of points of interest.
WildKnowledge	http://www.wildknowledge.co.uk	WildKnowledge(WK) allows users to create & share interactive forms, keys, maps or images for use on PCs,laptops or mobile devices.

Fig. 3. Query (d) result screenshot

6 Conclusion & Future Work

In this paper, we have discussed the need for an underlying context model for mobile education technology which we provide in the form of our context ontology COMET, derived from previous context ontologies. Specifically, we have divided COMET into three basic parts: learner-centric, environmental and activity. To evaluate the feasibility of our proposed ontology, we have defined an example by considering educator based scenarios. A web architecture is used to show how semantically rich descriptive model can usefully extract contextual data between different entities.

The work presented in this paper is still in early stages. We are currently working on the design of context and domain ontologies. We may leverage these ontologies to develop an adaptive learning environment. Further, our plans include personality traits of learners and other environmental context entities like sensor devices and environmental conditions that may be taken into account while representing domain knowledge to learners. Adaptations of the learning contents may be practically explored by using more developed real life scenarios. That might help us to understand how ontology-based systems can possess the necessary flexibility to respond to mobile learner activities in varying contexts.

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