m-LOCO: An Ontology-based Framework for Context-Aware Mobile Learning

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Abstract. Providing personalized and context-aware learning contents to the learners in mobile learning environments requires a precise and well-represented definition of the term "context" in such environments. In this paper we present an ontology-based framework, called m-LOCO, built on top of an integrated set of ontologies (e.g. learning design ontology, domain ontology, user model ontology and learning object ontology) with the goal of capturing contextual information in mobile learning environments. In this framework, potentials of mobile devices as content delivery media are utilized in the light of a socially-enhanced self-regulated learning approach to foster both individual and social learning skills of the learners. Moreover, to illustrate the benefits of the framework in providing personalized contents to the learners, as the major contributors of any learning process, we present a set of use case scenarios and demonstrate how the m-LOCO framework can be queried to fulfill the needs and requirements of each scenario.

Keywords: Ontologies, Learning Context, Mobile Learning, Context-Awareness

1 Introduction

Fulfilling the diverse range of learners' needs in e-learning environments, requires providing learners with contents not only personalized based on their individual characteristics - as in most of the traditional personalized systems -, but adapted to the learning situation, where the 'situational' information is the major factor in determining how the learning content is to be tailored for the learner. In particular, besides learner-centered factors, there are also environmental factors (such as the location and the available delivery media) that would have an inevitable influence on the learning outcome and performance of a learner.

The underlying idea of most E-Learning environments is to provide learners with "any time any where" learning experiences in comparison to traditional educational systems. The advent of mobile technologies and the rapid growth of their usage in everyday life are notably extending this ubiquity. Based on different pedagogical roles that they play (i.e., an assisting/recommender tool or the main delivery platform), mobile technologies can be leveraged to improve the learning outcome of a learner. The fact that

students normally use their mobile devices for spontaneous and short study phases makes mobile devices typically eligible for repetition, examination preparation or quickly looking up details when knowledge gaps are detected during the learning process.
All the information about the situation in which learning is occurring, can be referred to as the learning context. *Context* or *situational information* is any information that can be used to characterize the situation of an entity (i.e. a person, a place, or an object) that is considered to be relevant to the interaction between a user and an application [1].

To represent such contextual information about the learning situations with the goal of providing personalized and context-aware learning contents to the learners, concise yet comprehensive representation methods are required which, not only are expressive and extendable, but also have the potential to be reasoned over. Due to their flexibility, expressiveness and extendibility, we consider ontologies as the most suitable candidates for context representation in an open and ubiquitous environment. They also come with reasoning mechanisms over the available context data, making it possible to extract inferred knowledge out of the implicitly stated situations. Hence, to address the needs and requirements of a ubiquitous learning environment, we propose in this paper an ontology-based framework based on LOCO [2], an existing ontological framework for capturing and representing learning objects contextual data. Our work brings in novelty in this research area by demonstrating how LOCO can be extended to a generic ubiquitous learning environment capable of both capturing the contextual data occurring in a learning system and effectively querying this data in different use case scenarios to support an over-all personalization for the learners. We call this extended framework m-LOCO and build it upon the notion of learning context that is, a unique set of interrelated data characterizing a specific learning situation.

2 Ubiquitous Learning Context Models

Context-aware and ubiquitous applications have been the subject of debates among researches in different domain areas. Based on the requirements and characteristics of each of these domains, the term "context" has been interpreted in different ways and different approaches have been applied to capture the contextual information. One of these domains is Ubiquitous Learning environment. In particular a ubiquitous learning environment encompasses two underlying contexts, namely the learning context and the mobile/ubiquitous context.

In the scope of the learning context, like in other domains, different authors have different interpretations of the term "context". The authors in [1] define learning context as any instantaneous, detectable and relevant property of the environment, system, or users, while in [3] learning context is defined as meaningful set of properties about what surrounds and gives meaning to something else, which means that if we define a learning context of a learner, we should only consider properties that are meaningful to the learner. In another interesting interpretation, learning context is described as a subset of learning [4]. Finally, the authors in [5] infer that learning context is used to describe the current situation of a person related to a learning activity. However, as can be seen and despite of this diversity, researchers seem to agree that a learning context is about the environment, situations, tools, materials, people (in terms of social networking), and learning activities. Being more specific, context in e-learning systems is mostly characterized by *the learners, learning objects and learning path, where a set of learning activities is performed in the light of a specific pedagogical approach*.

Context in mobile and ubiquitous environments is summed up mainly in the spatial and temporal aspects of the user's situation. Based on the changes and properties of these two attributes, users of such systems would be informed of different personalized services available for them. For instance, in sample scenarios of the usage of the system described in [6], whenever the location of a particular user is outside of a specific area (e.g., the school), his parents would be notified or when the user is near a bank he would be reminded to pay the bills, if there are any unpaid ones. Consequently, we can define a mobile learning context as being the learning context captured with regards to its delivery medium, i.e., the mobile devices.

3 m-LOCO: An Ontology-Based Framework for Context-Aware Mobile Learning

Ontologies are one of the most functional means for representing contextual data. They map three basic concepts in a context model (classes, relationships and attributes) to the existing things in a domain [6]. Moreover, to interpret the actual usage data, ontologies may use rules for context reasoning, making the representation to be both flexible and extendable. The design of m-LOCO is built upon LOCO, the ontological framework introduced in [2]. Having an eye on the major attributes of a ubiquitous learning environment along with analyzing the functionalities and potentials of this generic framework, we managed to identify and design other features to be added to LOCO, in order to support learners with personalized services in a broader range of contexts (Fig. 1). The heart of the framework presented in [2] is LOCO, an ontology of Learning Object Context aimed at capturing the information about a specific context of use of a learning object in a specific learning design. LOCO is comprised of three main ontologies and extended via an additional set of properties to other relevant ontologies such as user modeling and subject domain ontologies. The three core ontologies are learning object content (which identifies the information objects within a learning object with the goal of making each component of the learning object directly accessible), learning design (specifies pedagogical information; inspired by the IMS-LD Information Model [7]) and LOCO-Cite ontology (which is actually the linkage point between the other ontologies).

3.1 Delivery Media: Mobile Ontology

With the proliferation of the mobile users, the application of mobile technology in teaching/learning has the potential to offer significant advantages. However, before a mobile device could be considered as the candidate delivery media for learning materials, its feasibility according to some general constraints should be evaluated. Some of these constrains are [8]: the size of the screen (this could be a limiting factor in the amount and type of the media that can be displayed); the lack of input devices (this would reduce usability and user interaction); limitations in collaborative activities and network connections, and hard/soft-ware compatibility issues.

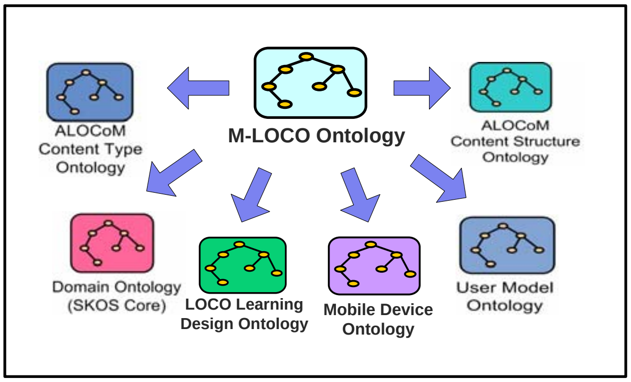

Fig. 1. The m-LOCO Ontology and its connections to other related ontologies

To be able to cover these device heterogeneities in a ubiquitous learning environment, we have designed an ontology of mobile devices based on the W3C's CC/PP (Composite Capability/Preference Profiles) specification [9] to be added to the LOCO framework. A CC/PP profile is a description of device capabilities and user preferences. Though this specification defines a schema that could be extended by other vocabularies for addressing specific requirements, it does not define a standard vocabulary. Currently, most CC/PP-capable devices use User Agent Profile Specification (UAProf), another specification originating from the Open Mobile Alliance (OMA) WAP forum [10], whose structure resembles CC/PP, but unlike CC/PP, it provides a set of vocabularies defined for describing device capabilities [11]. New devices usually have new capabilities and hence need new vocabularies that might not have been defined in the current versions of the specifications [12]. To address this issue, we take advantage of the extendible and flexible nature of ontologies and expect from the suggested ontology to be dynamic and growing. Accordingly, the classes (based on the above mentioned specifications) that are (currently) utilized in our ontology of mobile devices include (but are not restricted to):

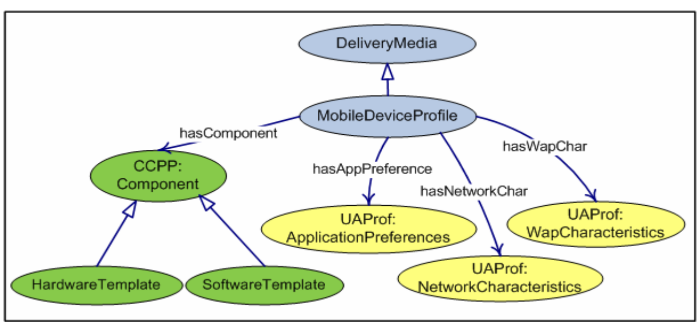

Fig. 2. The Delivery Media Extension

1. *TerminalHardware* (e.g., screen size, color/image capabilities, and manufacturer),
2. *TerminalSoftware* (e.g., operating system and list of audio and video encoders),

3. *ApplicationPreferences* (e.g., browser, supported markup and scripting languages),
4. *WAPCharacteristics* (e.g., WML script libraries, WAP version), and
5. *NetworkCharacteristics* (e.g., bearer characteristics such as latency and reliability).

3.2 Socially-Enhanced Pedagogy

Another important issue in every educational system is the pedagogical approach reflected in the learning scenario. This approach can be a combination of the strengths of different theories such as constructivism, social collaboration, self-regulated or action-oriented learning. Our goal is to provide learners with a learning environment in which they could be productive both as individuals and as team members. From a theoretical perspective, the underpinning pedagogical means to support this approach would be a self-regulatory learning design which is socially enhanced. To promote socially-enhanced self-regulated learning in our model, we consider enhancing the ontology of learning object contexts based on the cognitive activities the learners usually are engaged in within a cycle of self-regulated learning [14], namely:

1. *Forethought* (e.g. task analysis, goal setting, and strategic planning)
2. *Performance* (e.g. applying tactics and strategies to achieve those plans)
3. *Self-Reflection* (e.g. control/monitor the overall workflow by performing self evaluation against some standard such as prior-, others' - or a standard of performance)

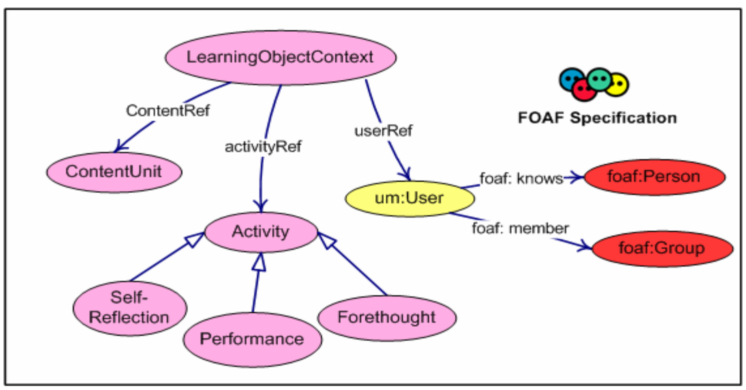

Fig. 3. The Extension to support Socially-enhanced Self Regulated Learning

To support the above cognitive activities, the *Activity* class of the LOCO framework is further extended (Fig. 3). Foreseeing the social collaboration of the learners during each activity of the learning design, we utilize the associated classes from the FOAF specification [16] to extend the *User* class of the learner ontology (Fig. 3). These collaborations can be utilized in a 'self-organized learning' approach, in that more complex tasks or problems can be broken down into parts, where each part can be mastered individually and at the end of a learning process, solutions would be exchanged between the individuals and combined into a final solution [15]. The FOAF specification provides basic expressions of personal information and relationships, and is a powerful and practical means for modeling online communities and keeping references of a learner's compatible/available peers.

4 Context Capturing in m-LOCO

The proposed ontological m-LOCO framework is advantageous both for learners and instructors. In this paper, however, due to space limits, we only focus on the learner centered scenarios. Fig. 4 exemplifies the overall architecture of a context-aware learning environment as an integrated set of ontological repositories which together utilize the potentials of the m-LOCO framework to locate, address and deliver personalized learning objects to learners. In this overall architecture different pieces of knowledge and data from different ontology-based repositories are integrated to shape the mobile learning context. For example, the user model repository contains data about the individual learners, such as their personal information, their background level of knowledge regarding the subject domain, their learning styles and preferences, as well as information about their social connections. The repository of learning objects includes information about the content structure (e.g. audio/video/text) and educational content types (e.g. example, overview or tutorial) of the learning contents. The delivery media repository contains data about the specifications and features of different available delivery media (which would be an indicator of their feasibility to different learning contexts). Thereby, to provide learners with contextually relevant learning objects, the overall architecture (Fig. 4) should be investigated.

We assume the presence of a learning object repository, from which teachers/learners or the system itself can select and retrieve appropriate learning objects. Moreover, in order to perform further analysis or reasoning, we need a context repository, in which learning objects' context-related data in accordance with the m-LOCO ontology is stored. This association means that each learning object from the learning object repository would have its context data in the repository of learning object contexts [2]. This context-related data can be captured in different ways. One approach is that, every time a learner selects a learning object from the learning object repository, the related contextual data would be gathered and stored in the repository. The other alternative is when the system intelligently suggests or delivers a learning object to a learner based on the gathered data from the learner's (partial) contextual information and the available or inferred facts and rules that already exist in the system. Samples of such contextual information might include data about the available delivery media that the learner has access to, data about other available peers, data about the learning history of the learner and data about the activities with the highest priorities that the learner is required to perform. Nonetheless, in both cases, a learning object context instance is created in the repository of learning object contexts and all relevant context-related data for that usage is stored in it.

To have a better illustration of the above architecture, in the following subsection we explain the potential functionalities of the system in sample scenarios and demonstrate how these functionalities can be fulfilled by querying the integrated ontology-based repositories.

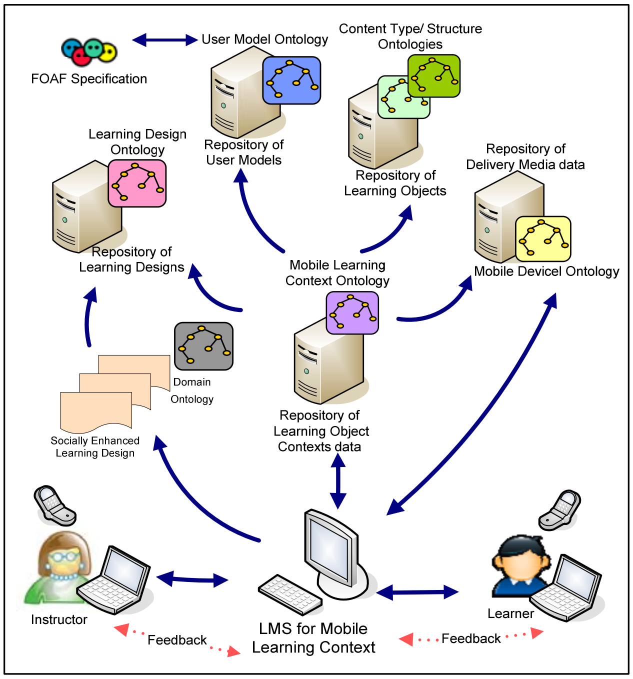

Fig. 4. The overall architecture of m-LOCO –based learning environments

5 Use Case Scenarios

From the learners' perspective, the basic and ultimate function of the framework is to provide them with appropriate learning objects. While locating these learning objects in the repository, the system will consider the contextual information of the present learning situation and provide the learners with those objects that are most appropriate for their present learning and mobile/ubiquitous context. For example, consider the following scenario: a student is in the bus on her way to the campus and decides to take advantage from this idle time and uses her PDA to connect to the learning system. Her contextual data firstly includes personal information about her (both as an individual and as a member of probably different social groups). Data about the subject domain and about the assigned learning activities based on the associated pedagogical model are other contextual data that come along with her user model. Moreover, the contextual data would contain information about the delivery media which in this specific case is a PDA (line 11). Based on this current in-use delivery media, we can query the repository of mobile learning object context data and utilize the already available context (lines 7-11). The following excerpt shows an instance of such a query in the SPARQL query language:

```
1 PREFIX loco: <http://lc.iat.sfu.ca/loco#>
2 PREFIX mloco: <http://lc.iat.sfu.ca/mloco#>
3 PREFIX co: <http://lc.iat.sfu.ca/content#>
```

```
 4 PREFIX rdf: <http://www.w3.org/1999/02/22-rdfsyntax-ns#>
 5 SELECT ?cu
 6 FROM <http://lc.iat.sfu.ca/mloco.rdf>
 7 WHERE {
 8 ?mloc mloco:contentRef ?cu.
 9 ?mloc mloco:hasDeliveryMedia ?md.
10 ?md rdf:type mloco:MobileDevice.
11 ?md mloco:hasComponent ?component.
12 ?component rdf:type mloco:HardwareTemplate.
13 ?component mloco:hasScreendim ?scrndim.
14 FILTER regex(?scrndim, "320,200", "i")}
```

To further utilize the social connections of the learner, we can query the repository of mobile learning object contexts focusing on the user models and the relationships expressed via FOAF properties. Consider another scenario in that, the system can pair a learner during each activity, with peers who are directly/indirectly linked to her in her social connections and, are performing the same activity (performance for example) in the same subject domain (see lines 15-19). The following excerpt reflects this query (in SPARQL), which aims to find another learner (lines 14-18) that would be a suitable peer for the learner and that the two of them know each other and (potentially) are members of the same group (see lines 6-10).

```
 1 PREFIX loco: <http://lc.iat.sfu.ca/loco#>
 2 PREFIX mloco: <http://lc.iat.sfu.ca/mloco#>
 3 PREFIX foaf:   <http://xmlns.com/foaf/0.1/>
 4 PREFIX um: http://lc.iat.sfu.ca/user-model#
 5 PREFIX rdf: <http://www.w3.org/1999/02/22-rdfsyntax-ns#>
 6 SELECT ?person
 7 FROM <http://lc.iat.sfu.ca/mloco.rdf>
 8 WHERE {
 9 ?mloc1 mloco:userRef ?learner.
10 ?learner um:hasID “AC56734”.
11 ?mloc1 mloco:activityRef ?act1.
12 ?act1 rdf:type mloco:Performance.
13 ?mloc1 mloco:contentRef ?citem.
14 ?learner foaf:member ?group.
15 ?mloc2 mloco:userRef ?person.
16 ?learner foaf:knows ?person.
17 ?mloc2 mloco:activityRef ?act2.
18 ?act2 rdf:type mloco:Performance.
19 ?mloc2 mloco:contentRef ?citem.
20 ?person foaf:member ?group.
```

Another scenario in terms of enhancing social collaboration in mobile learning can be when the learner is asking for assistance/help for a specific topic during an activity. In this case the system can traverse through the learner's social links and refers her to those peers of her whose level of skill in that subject domain makes them eligible to temporarily play the role of a tutor/assistant. The following query depicts how the mobile learning context repository can be queried when a learner posts a help request message (lines 8-12). This query seeks those peers of the learner (based on the properties specified via FOAF specification) whom the learner is connected to (lines 13-14) and whose level of performance in the domain topic where the learner is asking for help, is higher than a predefined value (lines 15-19).

```
PREFIX loco: <http://lc.iat.sfu.ca/loco#>
PREFIX mloco: <http://lc.iat.sfu.ca/mloco#>
PREFIX foaf:   <http://xmlns.com/foaf/0.1/>
PREFIX um: <http://lc.iat.sfu.ca/user-model#>
SELECT ?person
FROM <http://lc.iat.sfu.ca/mloco.rdf>
WHERE {
?mloc1 mloco:userRef ?learner.
?learner um:hasID “AC56734”.
?message loco:domainTopic ?dt.
?message loco:sentBy ?learner.
?learner foaf:knows ?person.
?person um:hasPerformance ?performance.
?performance um:performance_value ?pvalue.
?performance um:learning_competency ?competency.
?competency um:domainTopicRef ?dtRef.
FILTER (xsd:decimal(?pvalue) >= ‘threshold’ ^^ xsd:decimal)}
```

The above scenarios were related to the situations in which, the learner is in direct interaction with the system. However, there are also situations where the system, based on the contextual data and some predefined rules, can proactively provide the learners with suggested and recommended materials. A sample scenario of such a case can be when the system identifies, e.g. from the learner’s calendar or the course schedule, that the midterm test is in, let us say, two days. Based on the learner’s existing contextual data, the system can then infer that the mobile device is the most suitable delivery medium for both the learner and the context she is located in. Considering the domain ontology and the performed learning activities, the system would remind the learner of the midterm event and offer her links to the relevant learning content, such as relevant definitions, examples, exercises and the like. This scenario can be more intelligent, when the recommended links refer to those sections of the content material in which the learner has had a relatively lower performance. To be even further proactive, the system can also take advantage of the learner’s idle times, such as when the learner is commuting or waiting before start of a meeting, and suggests her the remedial materials which are suitable both for that period of (idle) time and compatible with the learners’ mobile device characteristics. The underlying reason for this sample use case is actually twofold: first, when a test or an exam is so close, learners usually do not have enough time to go through all the available learning contents, but need to quickly access the most relevant parts, specially the parts they have had problems in. Second, mobile devices are considered not to be suitable for long lasting learning activities [8]. They are, indeed, more proper for quick references and reminders.

6 Conclusions and Future Work

To realize the requirements of ubiquitous learning contexts, we came up with the idea of an ontology-based mobile learning framework. By enhancing an already existing ontological framework with two ontological extensions, the proposed framework (m-LOCO) supports learners in a broader range of situations such as mobile learning context. The first extension is an ontology-based representation of the delivery media in a mobile learning context. It should, however, be noted that the technical constrains in

mobile learning (e.g. limitations in device-to-device interaction) would impose some additional limitations on the learning process, which clearly demonstrates the need of a well-defined pedagogical approach. Thereby, we have designed the other extension in support of a socially-enhanced self regulated approach to be pursued in a mobile learning environment. To demonstrate the capabilities of the framework we have provided a set of sample use cases along with the associated queries which can be performed over the overall architecture to satisfy the requirements of each scenario.
To evaluate the effectiveness of the m-LOCO framework, our next step is to integrate it into a real learning environment. Such an environment brings multimodality opportunities for its users. In addition to performing evaluation methods such as precision and recall, evaluating the usability of the system would also indicate the efficiency level of the framework.

References

1. Dey, A.: Understanding & Using Context, Personal & Ubiquitous Computing, 5(1), (2001).
2. Jovanović, J., et al: Ontologies for Effective Use of Context in e-Learning Settings, Educational Technology & Society, 10 (3), 47-59, (2007).
3. Azouaou, F., Desmoulins, C.: Using & Modeling Context with Ontology in e-learning: the Case of Personal Annotations, Intl. WSh. on Appl. of Semantic Web Technologies for E-Learning, (2006).
4. Berri, J., et al.: Ontology-based framework for context-aware mobile learning, Proc. of Wireless Communications and Mobile Computing, Canada, (2006).
5. Derntl, M., et al: Modeling context-aware e-learning scenarios, PerCom WSh., (2005).
6. de Almeida, et al.: Using Ontologies in Context-Aware Applications. Proc. of Database and Expert Systems, Poland, (2006).
7. Knight, C., et al: An Ontology-Based Framework for Bridging Learning Design and Learning Content. Educational Technology & Society, 9 (1), (2006).
8. Kramer, B. J. et al.: Exploring the Use of Cellular Phones for Pervasive eLearning, Proc. of 4th Pervasive Computing and Communications Wsh., (2006).
9. http://www.w3.org/Mobile/CCPP/
10. Open Mobile Alliance, http://www.openmobilealliance.org/
11. User Agent Profile Specification, Wireless Application Group, Version 20 Oct 2001.
12. Eap, T. et al.: Personalized Mobile Learning Content Delivery: A Learner Centric Approach, Intl. Journal of Mobile Learning and Organization, (2008) (in press).
13. Hayes, P. Pathak,et al. : Cultural-Context of Mobile Learning using Activity Theory, Proc. of the 6th Annual Irish Educational Technology Users' Conference, (2005).
14. Pressley, M. : More about the development of self-regulation: Complex. Long term, and thoroughly social. Educational Psychologist, 30 (4), 207- 212. (1995).
15. Huber, G., et al., Structuring Group Interaction to Promote Thinking and Learning During Small Group Learning in High School Settings, In: The Teacher's Role in Implementing Cooperative Learning in the Classroom., pp. 110-131 , Springer, US, (2007).
16. FOAF Vocabulary Spec., http://xmlns.com/foaf/0.1/.