An Ontology for representing Context in User Interaction for enhancing Web Accessibility for All

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Abstract

Today, users of web-based platforms are generally heterogeneous and have different needs, and this is likely to increase in the future. The user interfaces of these systems are mostly direct manipulation interfaces. These Interfaces can considerably benefit from the semantic of context, it can adapt the utility of interaction styles and display modes depending largely on the surrounding environment, the user's needs and the characteristics of on-line resources.
In order to provide means for that, first we have to define how to better represent contextual information, second we have to reason about these information. In that respect, ontologies are an interesting approach since they enable reasoning, reusability and knowledge sharing. In this paper, we propose CO a Context Ontology using OWL to formally represent context in user interaction processes, that enhances the web accessibility.

1. Introduction

In recent years E-Learning systems have become very popular as educational tools which offer a great opportunity for people with mobility problems to access and to manipulate the on-line resources.
These systems provide an efficient way by direct manipulation interfaces to personalize the way the interface and the content are presented to the *learner*. The ability of such systems requires two kinds of descriptions: a description of the learner's preferences or needs and a description of the resource's relevant characteristics [1]. This concept has been addressed by the Instructional Management Systems (IMS) Global Learning Consortium in the IMS−*AccessForAll* Meta-data (MD) specification and the IMS Learner Information Profile (LIP) specifications. The later specifies what the user needs or prefers and the further labels the resources using the same terms [2] to match the needs and preferences of a learner's profile. The resource accessibility description is also being addressed by the *DC-Accessibility Element* [1].

However, most online educational environments are still not accessible to all users, since there are many electronic barriers that can impede access to on-line resources which don't support for instance assistive technologies like Screen Readers. At the same time, many user interface improvements based on the concept of *Context-Awareness* and *User Context* were achieved to enable able-bodied people to use their device in special occasions, e.g. the voice interface in the mobile phone such as SenSay [3], Light-Sensitive Display and Orientation-Sensitive User Interface integrated in some mobile devices. In the next phase the notion of context has been extended in the ubiquitous computing [4].
We believe, considering context may enhance the user interaction e.g. blind people using their mobile devices for E-Learning as well as presenting textual descriptions of images to users who aren't able to download images due to the bandwidth costs for instance when they are on mobile devices or when they are in a developing country.

For our purpose, we extend this concept with more awareness for context including environmental context, physical context, computing context and user context. Therefore, we present a Context Ontology CO, which captures all the

[1] `http://dublincore.org/groups/access/index.shtml`

context information within the user interaction. We plan in the future to use this ontology to enable the user interface characteristics to change automatically, according to dynamic user characteristics and situations that are detected at run-time from the Context Ontology. Furthermore, such concept can be very beneficial in enhancing web accessibility so that interfaces are not chosen in advance but rather could be generated in real-time upon the semantics in the Ontology.

The rest of this document is organized as the following: in the next section we introduce web accessibility together with E-Learning, then we discuss the shortcomings of some context-aware systems that make use of the Web Ontology Language OWL. In section 4 we present Context Ontology CO and the way we access its content. Future work and conclusions are given in the section 5.

2. Web accessibility and E-Learning

A web application is accessible if web users with disabilities can perform all the navigational tasks with ease [5]. Blind users also rely on audio to perform navigational tasks. From a technical point of view, web accessibility corresponds to making possible to any user, using any user agent (software or hardware to view web content) to understand and interact with a web site, despite of disabilities, languages or technological constraints. The W3C/WAI [6] Working Group offers standards which are internationally accepted. They offer quantifiable rules, however, web developers often fail to implement them effectively. One of the reasons is that most of the available accessibility guidelines appear too costly [5], however, there are many positive arguments for applying these rules: Major arguments are cited in [7]; social responsibility, sustainable technologies, financial benefits and legal liability. Indeed, by dealing with accessibility issues a larger number of people will use the site and hence one can realize substantial return on investment (ROI). In fact, accessibility benefits also older users, as the percentage of older users is increasing significantly, but also mobile device users, and other individuals. Therefore, accessibility notion has been enlarged in the IMS scope, for addressing not only impaired users' needs, but also other users' (learners') preferences, since the needs and preferences that are essential to a learner are a consequence of having a disability and/or it may be that the circumstances, devices, or other factors have led to mismatch between them and the resources they wish to use. In this context, the *Adaptive Technology Resource Centre (ATRC)*[2] at the University of Toronto sees disability *as a mismatch between the needs of the individual and the service, education, tools or environment provided and accessibility as the adaptability of the system to the needs of each individual*.

However, looking at the ageing societies and considering the requirement of life-long learning, the rapid emergence of E-Learning systems over the world even in developing countries, it becomes obvious, that the need for flexible user interfaces is increasing. People within higher and further education are confronted with the use of virtual learning environments (VLE), web-based trainings (WBT) and other E-learning applications and educational technologies. These technologies have to be accessible in order to enable all people to take part in education and the life-long learning.
Generally, main barriers to the use of E-Learning in developing countries are technology-based, e.g., lack of hardware, expensive and inappropriate software, limited access to technology and Internet, poor Internet connectivity, lack of technical support, and server breakdowns [8].

Thanks to the *Semantic Web*, which provides the ways for formal information representation of web resources, we build a Context Ontology, since ontologies have been proven an effective means for modeling digital collections in all domains for many reasons such as: a common ontology enables knowledge sharing and reasoning through performing automatic processing techniques i.e. rules. Since context is widely defined, we understand context as defined in [9]: *Context is any information that can be used to characterize the situation of an entity. An entity is a person, place or object that is considered relevant to the interaction between a user and an application, including the user and the application themselves*. This means that not all the properties of the context elements are considered, but only the meaningful ones regarding what the context is about.

In our case, we mean by context any information about a user, his/her environmental attributes (e.g., noise level, light intensity, temperature), his/her used devices, the activities and tasks in which user is engaged, and his/her situational roles, and intentions.

[2] `http://atrc.utoronto.ca/index.php`

3. Related works

In order to support context description, several approaches are possible, depending on the amount of information. Indeed, there are some standard specifications for the description of different context information. One interesting specification is the IMS−Learning Design (IMS-LD) [10], it uses an underlying narrative syntax (expressed in terms of roles playing activities using resources), which is oriented to the pedagogical description of learning experiences and may be not suitable for general purposes [2].

Since we speciffically focus on the interaction of a user with disabilities with web applications and their resources, we place the user, his/her enviroment and his/her tasks into the center of attention. Our goal is to study the different context informations which may have impacts on the presentation of information to the user.
Various representation formats are available for modeling the context. A recent proposal which handles both user and context has been the object of the research discussed in [11]. The work presents the Ontology GUMO [12], UbisWorld ontology [13] to model context information, and a service to distribute user and context models among different web-based, desktop, and mobile applications.

An important class of context-aware systems is moving toward pervasive, ubiquitous environments [14] [15] in which devices, software agents, and services are all expected to seamlessly integrate and cooperate in support of human objectives. This work [16] describes COBRA-ONT an Ontology for supporting pervasive context-aware systems together with an inference engine for reasoning with information expressed in the Ontology. The authors in [17], stressed that existing interfaces can be enhanced with context-aware techniques such as proximate selection, a method of presenting data that is ordered by proximity to the user. However, to fully exploit context-awareness new applications and user interface metaphors are required, such as situated information spaces [18]. In the domain of web search personalization, the authors presented in [19] a framework for contextual information access using ontologies and demonstrated that the semantic knowledge embedded in an ontology combined with long-term user profiles can be used to effectively tailor search results based on users' interests and preferences. For detecting the user's task the authors introduced in [20] an ontology-based user interaction context model that extends the spectrum of feature construction for automatic task detection. This work shows that using an ontology-based representation of the user's context enhances the performance of automatic task detection.

Many research projects to date have applied context to both enhance interfaces of traditional applications, however, none has taken advantage of the semantics of context for an automatic generation of user interface characteristics for all variety of users, bearing in mind the dynamic change of the context and the users' needs, so that interfaces are not chosen in advance. This will lead to an enhancement of web accessibility for a wide range of users.

4. Context Ontology CO

The CO's intention is to represent the context within the user's interaction, at the moment originating only manually, but in the future it is planned to originate from context sensors that automatically observe the user and measure some relevant environmental prameters (noise, light, etc ...) on his/her current situation within the interaction. There are many different types of contexts that a system can utilize: location, presence of objects or people, temperature, blood pressure of the user, etc. In fact any environmental factor that might influence the user interaction can be used, provided there is some mechanism for capturing it.

Instead of creating a new vocabulary from scratch we exploit many existing resources by extending and refining for instance [21]. According to [22], it is almost always worth considering what someone else has done and checking if one can refine and extend existing sources for our particular domain and task. However, the ontology can easily be enhanced by adding new concepts and relations. To facilitate the degree of flexibility in the definition of context as described above an open context model is in place. Furthermore, in order to enable broad tool support and to ensure computational completeness and decidability, the ontology has been developed with the aim to conform to the OWL-DL subset of the OWL Ontology language.

To keep the ontology simple, we have focused on the constraints which may have impact on the user interaction auch as noise and used software such as Assistive Technologies etc, as depicted in Figure 1. The tool used for modeling the ontology is the Protégé ontology modeling tool *Protégé-OWL Editor*[3]. The noise-related context have some common properties such as hasStartTime, hasDuration and hasDecibel. Place is also another concept in the ontology, which has city and zipcode. For example, a blind learner is interacting with his/her e-learning system, using Screen Reader like

[3]Protégé-OWL Editor: see `http://protege.stanford.edu`

Jaws in a noisy place like public internet access points (especially in many developing regions). The respresentation of a part of this scenario is given below.

```
<owl:Class rdf:ID="NaturalEnvironment">
 <rdfs:subClassOf rdf:resource="#EnvironmentContext" />
</owl:Class>
<owl:Class rdf:ID="Noise">
 <rdfs:subClassOf rdf:resource="#NaturalEnvironment" />
</owl:Class>
<owl:Class rdf:ID="Software">
 <rdfs:subClassOf rdf:resource="#ComputingContext" />
</owl:Class>
<owl:Class rdf:ID="AT">
 <rdfs:subClassOf rdf:resource="#Software" />
</owl:Class>
<owl:Class rdf:ID="Traffic">
 <rdfs:subClassOf rdf:resource="#Noise" />
</owl:Class>
<Traffic rdf:ID="StreetTraffic">
  <usedAT>Screen Reader</usedAT>
  <hasPlace>
 <Place rdf:ID="Office">
 <city rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Vienna</city>
 <zipCode rdf:datatype="http://www.w3.org/2001/XMLSchema#string">1100</zipCode>
   </Place>
  </hasPlace>
  <hasStartTime rdf:datatype="http://www.w3.org/2001/XMLSchema#time">
10:00:00</hasStartTime>
  <hasDuration rdf:datatype="http://www.w3.org/2001/XMLSchema#duration">
60</hasDuration>
  <hasDecibel>60</hasDecibel>
  <hasInjury rdf:datatype="http://www.w3.org/2001/XMLSchema#nonNegativeInteger">
1</hasInjury>
</Traffic>
```

In addition, by the use of the ontology we can achieve some reasoning. For this reason, we use sdlvhex [23] to reason and to rank the knowledge extracted according to their importance in user interaction. Dlvhex is a prototype application for computing the models of hex-programs [24]. Hex-programs originate from dl-programs and they are an extension of answer set programs for the integration of external computation sources. Dlvhex involves several plugins such as Description Logic Plugin [23] which interfaces OWL ontologies by using a reasoner. Therefore, we can refer to the ontology and access to the classes and the properties represented in the ontology by the use of dl-atoms. For example, DL[Noise] refers to the Noise class and DL[”hasDecibel”] refers to the hasDecibel property of the noise constraint in our ontology, according to the above scenario.

```
% Rules for selecting a part of the context.
% user context in user interaction is given by
% the below requirements:
% Using dl-atoms, we refer to our ontology
noiseConstraint(X) :- DL[Noise](X), not -noiseConstraint(X).

-noiseConstraint(X) :- DL[Noise](X), noiseConstraint(Y), X != Y.

deciBel(DB) :- noiseConstraint(X), DL["hasDecibel"](X,DB).

usedSoftware(US) :- noiseConstraint(X), DL["usedAT"](X,US).
```

When the above program is given as input to the dlvhex system, it return the following output:

```
{deciBel(60), usedSoftware("Screen Reader"), noiseConstraint("context.owl#StreetTraffic")}
{deciBel(40), usedSoftware("Screen Reader"), noiseConstraint("context.owl#AmplifiedSpeech")}
```

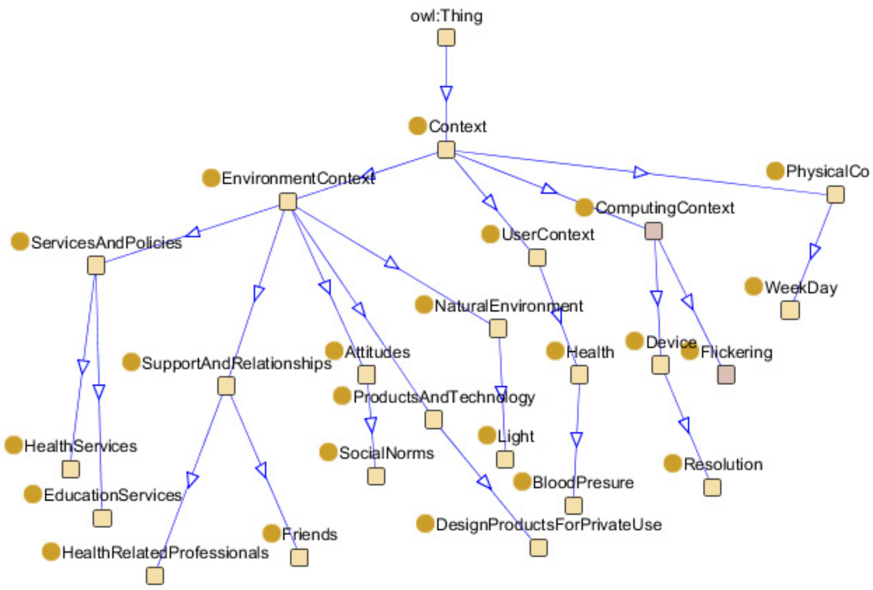

Figure 1. Concept hierarchy in Context Ontology

Next, with the use of weak constraints we allow our program to represent a quantitative cost specification of the constraints and using this feature we can limit the answer sets to the important in user interaction. From a top level perspective, we describe four different dimensions or main categories in our ontology:

1. User context: The user context describes what the user is doing, it can describe the user's intention, tasks, etc.

2. Physical context: This describes the spatio-temporal context that concernes with attributes like: time, location, etc.

3. Environmental context: This part captures the user's surrounding, such as things, light, people, and information accessed by the user, information about friends and relatives, the role the user plays, etc.

4. Computing context: This type of context captures the device type, properties, etc.

A small selection of Classes, Properties and Datatype Properties, used in the Ontology are described below :

- Context: A Context class.
- Activity: A subclass of the class UserContext
- hasResolution: A class property: A screen has resolution.
- course: A literal datatype property: The course attribute of the Activity class.

We plan to enable the user interface to change dynamically, according to dynamic user characteristics and situations that are detected at run-time from the context Ontology. The combination of concepts from other ontologies such as User Profile Ontology (UPO) and the presented Context Ontology are possible, so that for a color blind user, sitting in a high lighted place and using a PDA, an alternative non coloured information style would be presented and a Light-Sensitive Display would be activated.

5. Conclusion

We have presented a Context Ontology and we assume by using answer set semantics and dlvhex as a solver, we can generate more expressive rules. Furthermore, we plan to automatically derive relations between the concepts in the ontologies and automatically detect the user's intention.

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