Facilitating Mobile Users with Contextualized Content

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Abstract. We consider adaptation of content to various contextual details. The motivation for such adaptation results from the need for facilitating mobile users in their varying circumstances. The adaptation is based on a context ontology, which contains concepts for describing time, location, social aspects, and device characteristics. We briefly discuss a case-example of a personalized mobile portal demonstrating this contextual adaptability, and also include feedback from user trials.

1 Introduction

The web is changing from a static collection of web pages into a collection of services, which bring more dynamic content to the web [1]. Not only corporations, but also individual users can produce and publish this dynamic content. This paper deals with mobile users utilizing hand-held devices to access the Internet. In addition to consuming the content they find in the Internet, the users also create it themselves.

Certain aspects are to be taken into account when producing content for mobile users. First of all, people access this content with diverse devices. These devices have varying display sizes, processing capacities, storage spaces, etc., that have impact on the adaptation of the content. Secondly, mobile users access the content in different locations, like at the office, at home, or while straying around in a foreign city, as depicted in Figure 1. Third, time has impact on the adaptation; content can be accessed at night, on weekends, in winter, etc. Finally, various social aspects can affect the adaptational details. Examples are groups such as work community or family, moods like happy or tired, and modes of spending time such as being on vacation or driving to work.

In addition to the contextual characteristics, people can have permanent preferences they want to apply regardless of the situational details. Examples are social security number, address, and affiliation information. This paper focuses on the contextual details, leaving the permanent information out of the limelight.

The rest of the paper is organized as follows: In the next section we discuss the contextual ontology that underlies the adaptation. Section 3 considers semantics-based adaptation. A case-example of a context-aware mobile portal and some results of its user trials are presented in section 4. Finally, section 5 discusses related work and is followed by section 6 that contains concluding remarks and our future work around the area.

Fig. 1. Accessing content in various locations

2 Context Ontology

In [17], our context ontology is presented at a general level. This section gives a more detailed description, containing RDF Schema [21] excerpts of the ontology, as well as discussion on the applicability of various contextual information. We do not include the whole ontology here, since the concepts are defined in a uniform manner and these excerpts are enough for transmitting its general structure.

Our ontology is frame-based [12], consisting of classes and properties characterizing them. The properties are either simple or complex. Simple properties have literals of some kind as their values. Values of complex properties, on the other hand, are further classes. Class-attribute is the only relation found in our ontology; we have not defined axioms or other interdependencies between the concepts apart from natural language recommendations given inside some comment tags. *ContextualProperties* is the topmost class for representing contextual information. The following RDF serialization contains definitions for the *ContextualProperties* class itself, as well as one of its properties, namely *location*:

```
<rdf:Description rdf:about="ContextualProperties">
   <rdf:type rdf:resource="&rdfs;Class"/>
   <rdfs:subClassOf rdf:resource="&rdfs;Resource"/>
</rdf:Description>

<rdf:Description rdf:about="location">
  <rdf:type rdf:resource="&rdf;Property"/>
  <rdfs:domain rdf:resource="#ContextualProperties"/>
  <rdfs:range rdf:resource="#LocationInfo"/>
</rdf:Description>
```

The concepts discussed in the following subsections are serialized in RDF in a similar manner. Class names begin with capital letters and property names with small letters. Simple properties, also called datatype properties, use definitions of XML Schema [18] in the same way OWL [20] does. Utilized URIs are abbreviated as follows:

– `&rdf;` refers to `http://www.w3.org/1999/02/22-rdf-syntax-ns#`
– `&rdfs;` refers to `http://www.w3.org/2000/01/rdf-schema#`
– `&xsd;` refers to `http://www.w3.org/2001/XMLSchema#`

2.1 Time and Place

Time is the easiest kind of contextual information to be taken into account when designing adaptable services. Virtually every electronic device has a clock of some kind inside and connected to its processors. Our ontology introduces simple properties such as *timeOfDay* and *weekend*, as well as complex ones, such as *event*. *Event*-class, in turn, has further properties like *beginDate* and *eventName*.

Expressing location information requires a little more from the device than expressing time does. The device must have abilities for automatically retrieving its current location and presenting it to the user. Examples are GPS-devices, mobile phones, and WLAN-equipped devices. In our ontology we have a class called *LocationInfo*, which has simple properties such as *direction* the user is currently heading to. In addition, it has complex properties such as *address*, pointing to *Address*-class, which in turn has useful properties for describing an address, such as *streetNumber*. These examples are serialized as follows:

```
<rdf:Description rdf:about="LocationInfo">
   <rdf:type rdf:resource="&rdfs;Class"/>
   <rdfs:subClassOf rdf:resource="&rdfs;Resource"/>
</rdf:Description>

<rdf:Description rdf:about="direction">
  <rdf:type rdf:resource="&rdf;Property"/>
  <rdfs:domain rdf:resource="#LocationInfo"/>
  <rdfs:range rdf:resource="&xsd;string"/>
</rdf:Description>

<rdf:Description rdf:about="address">
  <rdf:type rdf:resource="&rdf;Property"/>
  <rdfs:domain rdf:resource="#LocationInfo"/>
  <rdfs:range rdf:resource="#Address"/>
</rdf:Description>

<rdf:Description rdf:about="Address">
   <rdf:type rdf:resource="&rdfs;Class"/>
   <rdfs:subClassOf rdf:resource="&rdfs;Resource"/>
</rdf:Description>

<rdf:Description rdf:about="streetNumber">
```

```
  <rdf:type rdf:resource="&rdf;Property"/>
  <rdfs:domain rdf:resource="#Address"/>
  <rdfs:range rdf:resource="&xsd;positiveInteger"/>
</rdf:Description>
```

Location information does not exhaustively cover everything there is to describing a location. Instead, like other contextual categories, it acts as an upper ontology and can be extended, as depicted in Figure 3. For example, a complex property of *EnvironmentalAttributes* could be introduced as an extension to the *LocationInfo* class. It might contain further properties for describing noise-level, light intensity, and temperature [2].

2.2 Social Contexts

Social contexts refer to details that have something to do with human nature or culture. Time and place can characterize *any* physical object, but social contexts only humans. We separate the social contexts into following three categories: State of mind (or mood) of the user, mode of spending time, and group contexts. These are generally harder to automatically detect than time or location. Group contexts can to some extent be expressed with closeness sensors aware of members belonging in the same group. User's emotional state of mind could in principle be partially retrieved through sensors attached to her skin. At the moment, however, automatically retrieving these in a useful way is science fiction. Furthermore, detecting mode of spending time automatically is even harder to achieve. How could current technology sense, for example, whether the user is working or not when he is writing something with his computer?

In our ontology, *mode* of spending time and *mood* of the user are simple properties that have string values. They are properties of a class called *State*, which is intended to express information related to one user. *Group*, instead, describes a number of people that have something in common. *Group* is defined as a class containing the name and type of the group as well as information about its members.

2.3 Device Characteristics

One important kind of information are details characterizing the device that is used for accessing the services or other content. Although also device-related data can be categorized as contextual information, it was excluded from our context ontology. Instead, existing UAProf [13] specification by OMA[3] was utilized. We had previous experience of using UAProf, as reported in [4], so adopting it was straightforward.

UAProf is based on W3C's[4] CC/PP [19], which has an RDF serialization and is therefore suitable for merging with the context ontology. Another potential option would be to use FIPA[5] Device Ontology [3], which has similar class-based structure as our context ontology does.

3 Open Mobile Alliance, http://www.openmobilealliance.org/
4 World Wide Web Consortium, http://www.w3c.org
5 Foundation for Intelligent Physical Agents, http://www.fipa.org

Current UAProf specification contains over fifty parameters for describing details of devices and networks. Example parameters are screen size, operating system, supported markup languages, and network latency. Typically UAProf is used as a URI reference to a shared set of preference data characterizing similar enough devices. UAProf's "default description block" defines a set of default values for a device group. Those values can be altered to describe hardware and/or software extensions, such as memory upgrade or a new email software.

3 Semantics-based Contextual Content Adaptation

One of the key challenges of the Semantic Web is the adaptation of web content according to diverse parameters. Contextual information and preferences of users should be taken into account in order for a flexible and proactive Semantic Web to emerge. The context ontology described above is intended to facilitate such adaptation. Figure 2 depicts the role of contextual information from a message receiver's point of view. Only the messages that conform to the details of the user's current active context(s) pass the "contextual boundary" and are delivered to the user. By setting his contexts public the user can reduce the number of undelivered messages. This presupposes, however, that the message senders check the public contexts of the user and try not to send messages that do not conform to his contextual restrictions. Delivering contextualized messages is discussed in more detail in section 4.

In our overall system we have also device-specific adaptation for mediatypes and markup languages. That adaptation is for displaying things in a format that fits the device restrictions and is therefore outside the scope of this paper. Instead, adaptation reported in this paper is based on the meanings of concepts encoded in the context ontology, as well as their appropriate combinations. Relevant device-specific information would be for example whether the user wants to apply some device while in a certain context or not.

3.1 Combining the Contexts

Combining the contexts is currently performed with three Boolean operators, namely AND, OR, and NOT. An example of a composite context would be "In a rock-concert" containing name and location of the venue (Shoreline Amphitheatre, Mountain View), time of the concert (8PM-11PM, 13.6.2003), mood (Excited), and contact information (SMS only). These would all be connected with AND-operator. Additionally, mode of spending time (Working) could be attached to this context with a NOT-operator to ensure that work-related messages do not interfere with leisure-time. Should the user be a frequent concert-goer, he might attach several individual concerts under the "In a rock-concert" context with an OR-operator.

Note that these operators are not present in the actual context ontology, but are instead functionalities on top of that. The ontology itself contains merely the classes and their properties in an appropriate hierarchy. This makes our system modular and leaves us room in the future to either extend or completely replace our current context combination and adaptation mechanisms without having to tamper with the ontology.

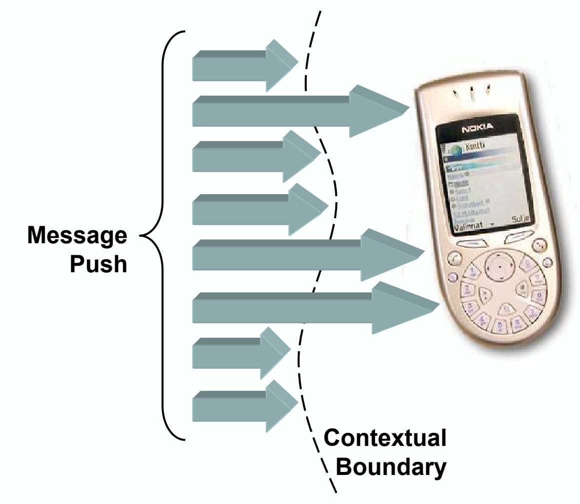

Fig. 2. Delivering contextual messages

So in addition to the possible ontology extensions already mentioned, our system might also be supplemented with reasoning based on, say, fuzzy or modal logic for deciding the current context and preferences of the user. This modularity is depicted in Figure 3.

3.2 Reusing Ontologies

One driving idea behind the Semantic Web is the distribution of ontologies across the Internet. Our approach conforms with this vision in that we intend to reuse as many existing ontologies and specifications as possible in order to avoid reinventing the wheel. Also, we are not ourselves in the business of building a huge ontology such as Cyc [10]. That said, the only ontology we are at the moment able to utilize in practice is the one characterizing devices, namely UAProf.

At the conceptual level, however, we have gone through existing efforts and considered them when specifying our context ontology. For example, specifications of LIF[6] were considered with location parameters. Wireless Village[7] presence attributes were recognized with parameters for mood. Taking potential third party developers into account, we also provide a pointer to the actual specification, as follows:

```
<rdf:Description rdf:about="mood">
  <rdf:type rdf:resource="&rdf;Property" />
  <rdfs:domain rdf:resource="#State"/>
  <rdfs:range rdf:resource="&xsd;string" />
  <rdfs:comment>User's emotional state. This parameter
  and the reserved values conform with the Wireless
```

[6] Location Interoperability Forum, http://www.openmobilealliance.org/lif/
[7] http://www.openmobilealliance.org/wirelessvillage/

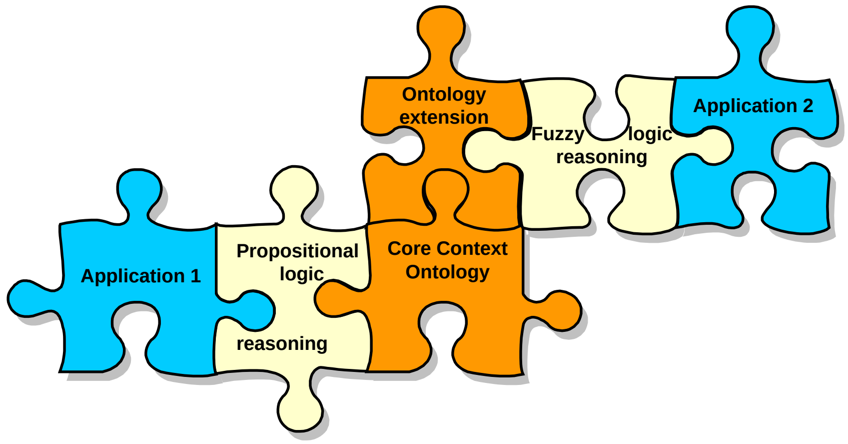

Fig. 3. Modularity of the system

```
  Village Presence Attributes specification, available at
  http://www.openmobilealliance.org/wirelessvillage/
  </rdfs:comment>
</rdf:Description>
```

In other words, although we have at the moment our own definitions for all contextual information apart from the device characteristics, possible merging of our definitions with existing efforts also at the technological level is foreseen.

4 Case-example and User Trials

We developed a context-aware mobile portal to demonstrate the utilization of contextual information and tested it with users. Preliminary results of the pilot trial as well as plans for upcoming trials are reported in [7, 5]. The portal is based on earlier efforts, namely an adaptation proxy and media conversions, which are described in detail in [6]. The mobile portal developed on top of that work and summarized in this section demonstrates a personalized service taking into account the details related to individual users. The portal is implemented both in WML and in XHTML. The context ontology was in the first demonstration not serialized in RDF, but instead in a proprietary XML dialect.

Of the above context ontology categories, the demonstration supports automatic activation of time- and location-based contexts. Time-based contexts can be either single or weekly occurring events. Location-based contexts are defined by coordinates and a radius, and are retrieved from whatever positioning system is available. Social contexts can be activated only manually, due to limitations of today's technology, requiring more efforts from the users. On the other hand, this way the system is flexible in allowing the users to create their own contexts without forcing them to place the contexts into any categories of the predefined context ontology.

Fig. 4. Front page of the mobile portal

The service introduces four main items, which are displayed in the personalized home page of the portal: Messages, Friends, Services, and Zones, as depicted in Figure 4. The term “Zone” was chosen over “Context”, because it seemed less abstract to the users. Messages can be sent to various Friends, and in addition “dropped off” in various Zones. For example, A can send a message to B so that B receives it only once she has arrived in a certain location such as golf club, and in a certain time such as Saturday morning. Here two contexts, location-related (golf club) and time-related (Saturday morning), are combined with an AND-operator.

Push functionality of WAP is used in the demonstration to inform users entering a Zone if they have Messages waiting for them. Because contextual messaging is highly asynchronous and the sender cannot be certain when the Message is delivered to the receiver—if it is at all—we added a functionality to set an expiration date to Messages. Undelivered Messages are automatically deleted when they expire.

Both the user interviews conducted before the software demonstration and the actual user trials indicated the need for group contexts. Users like to share their contexts with others and also keep track of their friends’ whereabouts and contact details, as depicted in Figure 5. By sharing their context the users felt more aware of their social surroundings. Sharing could be comforting, useful, or just fun. If the Zone description indicates a passive activity, it can spark others to contact the user. Some were inclined to include a description of their mood, i.e.: ”Emotionally crippled after a visit, recovering in my nest”. Depending on the user, there could be quite a bit of tinkering with the contexts. Some were content with the default contexts. Note that users’ privacy was preserved, since everyone had the possibility of determining the people or groups allowed to view their contexts.

We implemented three different means of group messaging. “One by one” method is the most traditional, and it means that once a member of the recipient group enters the

Fig. 5. Current contexts of friends

Zone, he receives the Message. “All after one” differs from “One by one” in that it delivers the Message to *all* members of the recipient group when *one* member has entered the Zone. Finally, “All after all” method delivers the message to *all* group members only after *each and every one* of them has entered the Zone.

The portal also provides a set of personalized links, indicated by the notion of Services. Links, along with any content such as notes, can be connected to contexts. If a context is inactive, links connected to it are not visible to the user. The user in Figure 4 has one active context, namely “Hard at work”. The name of the context is presented as a link, which can be used to access the content associated with it.

User trials in spring 2003 showed that users find social contexts both useful and fun. The most evident way of using the social contexts was to view the availability and activities of other users. The most promising way of using social context for communication was filtering the messages. When in ”On vacation” context, for example, the user may not want to receive Messages related to work. Also, contextual information was seen at its most useful with time critical cases, such as finding out the schedule of the next train to a certain destination when arriving in a train station.

5 Related Work

Providing contextualized content for mobile users gathers a lot of attention at the moment. It is recognized that information content should be filtered, personalized, and adjusted to situational conditions. In [9], the authors discuss an agent-based architecture for bringing contextualized content to mobile devices of tourists, taking into account various networks, QoS details, users’ locations, and device details. Delivering weather information, locations of friends, and other contextualized content to mobile devices on a campus environment is discussed in [15]. Contextual information related to “intelligent spaces”, i.e., environments equipped with computing devices, is discussed in [2].

The authors specify an ontology covering relevant concepts and relationships between them, which is intended for describing intelligent spaces and also agents (both software and human) acting in them. They provide an OWL-serialization for the ontology. Our approach differs with these in that we focus on the creation of ontology-based contexts by the end users. We also put more emphasis on social contexts, even though currently only location and time can be activated automatically.

Enhancing UDDI[8] to handle more enriched service descriptions, including contextual information, is discussed in [14]. The authors recognize following categories of contextual information: environmental elements, personal elements, task-related elements, social elements, historical elements, and spatio-temporal elements. Environmental elements are for example weather conditions. Personal elements are what we identify more as permanent preferences of a user, such as favorite color or hobbies. Social elements are what we call group contexts. Our conception of a social context includes also emotional state (mood) and mode of spending time. Task-elements are somewhat equivalent with our modes of spending time. The notion of historical elements is not elaborated in the paper in a more detail, but we assume that it concerns past behavior of the user and creates contextual information based the statistical analysis of that. Spatio-temporal elements are what we refer to with the notions of location and time.

A more futuristic scenario is presented in [8], in which the authors discuss visiting a museum. The scenario is filled with ubiquitous computing and introduces the notion of *semantic gadgets*, which are devices capable of semantic discovery and coalition formation. For example, when the user exits the museum and is approaching his car in the museum's parking garage, his handheld device automatically unlocks the doors of the car. And when connected to the car's recharger, the device utilizes the bigger display on the dashboard for improving the user experience.

In [16], the authors discuss how communicating with mobile phones can be facilitated with knowledge of the recipient's current context. This is contrasted with the nowadays evident decision to either turn the mobile phone completely off or at least mute it and potentially miss an important call, or to leave it on and likely receive also unimportant calls. This work is relevant at least with respect to social contexts and the "Friends" functionality of our system. Finally in [11], the authors discuss a user-centered location model, which takes into account user's position and relates it with time thereby enabling for example route planning. In addition, and more importantly as far as the work of this paper is concerned, their system also allows users to classify the locations they visit and attach various information to them.

6 Conclusions and Future Work

This paper outlined an ontology for describing contextual information. In addition, a case-example of personalized mobile portal utilizing the ontology for adaptational purposes was presented. User interviews and trial results indicated that there is a need for adaptating services and messaging to contextual details.

Our future work includes conducting more user trials. The trials will take place in fall 2003. One of the focus points will be a context-aware guide at an event in Finland,

[8] Universal Description, Discovery, and Integration, http://uddi.org/

namely Tampere Theatre festival. Users participating in the trial will receive contextual information about various events during the festival.

In addition, among our future work will be upgrading the demo software to be capable of handling RDF descriptions of contextual information. At the moment we do have an editor for creating contexts in RDF that are based on RDF Schema serialization of the context ontology, but we have not yet merged it with the rest of the software.

Further, we are planning of upgrading the ontology from mere RDF Schema to OWL. OWL is an extension of RDF Schema, with more expressive properties such as cardinalities. Using OWL would allow us to express more complex relationships between the concepts of the context ontology, such as those reported in [2]. However, our intention is not to strain our ontology with too detailed and fancy features, since it is intended to be used for context creation by everyday mobile device users.

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