The Ubiquitous Web as a model to lead our environments to their full potential

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1. Introduction

Our surrounding environment is becoming increasingly populated by devices and appliances that act as information and service sources, where no standardized means of knowledge interchange and workflow exist. The Web architecture and knowledge model - featuring links among information entities and conceptual, non-physical distances - has provided a common infrastructure to build up services that promote all types of inter-people and inter-processes interactions.

Ubiquitous computing systems are facing today similar problems to those some web technologies have faced in the past: lack of interoperability and lack of a driving initiative that establishes well-known and accepted standards. As a result, people cannot take advantage of the huge potential of their living or working environments.

In our view, the web model can be fully applied to everyday environments in order to transmute physical objects into smart resources to develop visions such as Ambient Intelligence [1].

We envision the Ubiquitous Web (UW) as a pervasive web infrastructure in which all physical objects are resources accessible by URIs, providing information and services that enrich users' experiences in their physical context as the web does in the cyberspace.

From our point of view, these are the some goals the UW should achieve:

- Every physical resource should be addressable, through a URI, in order to make accessible its information/services.
- The Web provides universal access to resources, but users carry out their activities in concrete places/locations. UW user agents should be more location-aware than traditional web browsers, yet allowing the experience of universal access.
- Any resource should be context-aware, especially user-aware, and could be annotated and defined by users in order to gain significance.
- Every physical resource should have different facets that could be enriched in a collaborative manner, augmenting its faculties. Examples of such facets could be information, services, interactivity and so forth.

In our research, we have found different strategies of applying state-of-the-art web technologies to pervasive computing environments. In this position paper we review past experiences from different initiatives, and include our own ones as examples of future potentialities: social annotation of physical objects/places and semantic web powered awareness applied to user-adaptation in everyday environments.

2. Social Annotation on Physical Objects

The Ubiquitous Web vision may be achieved by adding context-aware social tagging to physical objects. In what follows we offer some rationale that sustains such statement.

Before this workshop initiative, other researchers have already considered the convergence of web-related technologies and ubiquitous computing. A good example of this was the CoolTown project [2]. Its main goal was to support “web presence” for people, places and things. They used URIs for addressing, physical URI beaconing and sensing of URIs for discovery, and localized web servers for directories in order to create a location-aware ubiquitous system to support nomadic users. This vision resembles very much the definition of Ubiquitous Web as a net of knowledge where every physical object is web-accessible and interlinked.

Social tagging has become a very efficient way of categorizing. Folksonomies [3], a portmanteau of folk and taxonomy, allow content users to easily and informally describe web sites, documents, etc. using simple non–hierarchical tags. A good example of a folksonomy is the del.icio.us website [4], where users can open an account, bookmark their favorite web sites, and then tag each bookmark with their own keywords. One of the strengths of del.icio.us is the ability to see what other links (ours or other users’) have been tagged with the same keyword, as well as browsing through lists of ‘related tags’. Mathes [5] identifies the following strengths and limitations of folksonomies:

Strengths

- Browsing vs. finding: The use of social tags, and the proximity relationships between them, allow for easy browsing of folksonomies, jumping from one concept to a related concept.
- Desire lines: Desire lines are the “foot–worn paths that sometimes appear in a landscape over time”. Since folksonomies allow users to use their own vocabulary, instead of conforming to some limited vocabulary in a more rigid classification system, they allow us to discern the conceptual desire lines of users.
- Small barrier to entry: Using folksonomies, which have a flat space of keywords, requires no special training.

Limitations

- Ambiguity: Using an uncontrolled vocabulary, some tags can be ambiguous. For example, a website on C/C++ programming and a website on linear programming might both be tagged by users with the word programming, even though they obviously refer to two different types of programming.
- Spaces, multiple words: Popular folksonomies, like del.icio.us, do not allow the use of spaces or multiple words in the tags.
- Synonyms: There is no synonym control in folksonomies, which can lead to multiple tags having the same meaning (especially singular vs. plural tags).

- Only addresses the standard web of documents and not the web of resources pursued by Ubiquitous Web.

An interesting extrapolation of social tagging may be what we call **GeoFolksonomies:** the result of social tagging of geographic representations such as maps, plans, or any other topographic representation of an environment. The web stite Tagzania – tagging the planet (http://www.tagzania.com), which mixes two Web 2.0 [6]-based services such as Google Maps and del.icio.us is a good example of this idea. The main limitation of Tagzania is that the augmented world it creates can only be navigated by means of a browser. It would be more interesting if a nomadic user could encounter web-accessible resources as he moves.

The stick-e notes [7], an infrastructure enabling the edition, discovery and navigation of virtual context-aware post-it notes, was one of the first examples of **Ubiquitous Folksonony**, a mechanism where everything (a location, an object or even a person) can be augmented with an XML document (stick-e note) which can later be discovered and matched, taking into consideration the contextual attributes associated to a tag. This matching process carried out in the user's mobile device by an inference engine is undertaken in a spontaneous push-based manner. Some example contextual attributes against which the engine can match can be the profile of the tag author, the location where the tag was created, the time interval in which that tag should be available, and so on.

An application of the the stick-e note concept to the Ubiquitous Web may lead us to the concept of **AwareFolksonomies**. In this vision, users may associate objects with contextual attributes and metadata. By contextual attributes we understand the conditions under which the metadata associated to those objects may be triggered. We deem that Ubiquitous Web should lead us towards the creation of mobile social software communities, where users both real and virtual may discover folksonomies about everyday physical objects augmented with tags.

In order to make the matching between tagged objects and user preferences and context it would be interesting to transform the unstructured folksonomies into more structured forms ready for automatic reasoning by machines, such as ontologies. Towards this goal we believe two contributions would be paramount:

- A folk2onto tool will take a list of resources from a folksonomy and map them into a particular ontology, which will make those resources easier to process automatically
- A reasoning engine which operates on the outcome of the folk2onto in order to infer new relations among attributes of a tag and different tags. This tool could also operate, although in a much simpler manner, directly over the folksonomies.

3. Semantic web powered awareness and user-adaptation

We coined the term "Pervasive Semantic Web" [8] for designating the result of applying Semantic Web technologies to Pervasive Computing scenarios, thus, creating location-constrained microwebs where information flows go back and forth among devices and objects in the environment.

We have designed an interaction model for this architecture based on existing well-known technologies such as UPnP, XML, RDF or OWL, called SOAM (Smart

Objects Awareness and Adaptation Model). SOAM results can serve as an experience for further development of a web model for ubiquitous computing scenarios.

Since devices are information sources, they act so, providing semantic annotated data of perceived information such as temperature, time information, TV set state (channel, show, volume level) and even user location, the most classical context-awareness information.

Semantic information is exchanged among devices under request. Any device can discover who provides domain-specific information, by retrieving device capabilities, stating which kind of information a device can provide. We consider ontologies and RDF as the appropriate mechanism for representing domain knowledge and perceived information.

Once a device has gathered required information from other sources, it can apply reasoning mechanisms based on descriptive logics as well as traditional rules, to obtain some conclusions that increase the knowledge base of the device. Languages such as RuleML or SWRL can be applied, allowing even rules exchange among objects.

Since humans are the center of this vision, all those information flows have as unique purpose to best serve people. That goal can be accomplished by perceiving user's goal and try to adapt the environment for helping to achieve this goal. User's goal can be obtained explicitly by the user, or implicitly by observing his behavior, and act as input for aware devices. Moreover, user-profiles can be disseminated throughout the environment to inform devices about user preferences.

Once user's goals are determined, some kind of coordination must be performed and agreed by devices, in order to modify their behavior appropriately. Again, state-of-the-art web technologies such as WS-CDL, BPEL4WS, and others could be adapted for application here.

Summarizing, we think that several existing and currently under development web technologies can be applied or adapted in different aspects to accomplish the vision of Ubiquitous Web from the point of view of creating reactive environments:

- Communication and messaging: UPnP, HTTP.
- Context-awareness, capabilities description and user-profiles/preferences: OWL, RDF, CC/PP.
- Reasoning: OWL, RuleML, SWRL or the output of the Rule Interchange Format Working Group.
- Coordinated reactivity: WS-CDL, BPEL4WS.

One of the main problems for developing this vision is that most of those technologies have been designed for execution at computing facilities, rather different from those that will host the Ubiquitous Web model. **Taking the existing web technologies as a base, we argue that adaptation is needed in most cases to simplify and adequate their application to UW systems**.

4. Conclusion

As conclusion we suggest the following inputs for the workshop:

- Definition of Ubiquitous Web as a context-aware (especially, location- and user-aware) knowledge and communication model to augment users' experience in their physical context as the web does in cyberspace.
- Technical characterization of the Ubiquitous Web as the adaptation of existing web technologies and creation of new ones for this purpose.
- The need to explore mechanisms for the transmutation of physical objects into UW-enabled smart resources.
- Social tagging of those resources as a means to increase user's experience.
- Automatic adaptation of the environment to user preferences as a means to increase user's experience.

We presume that the Ubiquitous Web concept is a multifaceted prism that needs some polishing before becoming fully functional, and we expect the workshop can contribute with some concrete directions to achieve this.

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