A Context-Aware Mobile Mash-up for Ubiquitous Web

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Abstract. The Ubiquitous Web (UW) defines a pervasive web infrastructure where all physical objects are resources accessible by URIs, providing information and services that enrich users' experiences in their physical context. Thus, applying cutting-edge web technologies as middleware infrastructure for intelligent environments may be a good approach to materialize the Ambient Intelligence vision. This paper analyses this conjecture by describing how the combination of social context-aware annotation of objects and spatial regions, and sentient mobile devices might enable advanced context-aware data retrieval and service interaction within an opened uncontrolled environment, e.g. a university campus.

1 Introduction

The main goal of Ambient Intelligence (AmI) [15] is to adapt *intelligently* the behaviour of a context-aware environment to our preferences and habits, so that our daily life is facilitated and enhanced.

Archetype intelligent environments are usually instrumented with a plethora of sensors and actuators in order to proactively provide users with smart services that enhance their daily activities. Unfortunately, this heavy infrastructure requirement (costly and difficult to install and maintain) has been the reason why AmI-enhanced environments are still far from being the norm.

Nowadays, a user is usually accompanied anywhere at anytime by a mobile device that can act as his proxy/intermediary with the surrounding environment, and enable rich interactions with it. The combination of highly instrumented environments and mobile devices leads to two main types of user-environment interaction:

- *Explicit user-controlled interaction* where the user is always kept in the loop, has the last word, and the environment only suggests possible services and
- *Implicit system-controlled interaction* where the environment triggers service execution proactively, based on the user captured context, profile and preferences, anticipating to user needs, sometimes leading to importunate unwanted behaviours.

However, users accompanied by smart mobile devices do not necessarily need to encounter within an intelligent instrumented environment in order to profit from smart services, as it will be shown in this work. In fact, a key aspect for the success of Ambient Intelligence, i.e. maximizing its market penetration, will be to foster the use

of off-the-shelf infrastructure, without imposing on organisations willing to adopt AmI costly investments and cutting edge infrastructure deployment and installation hassles.

This work explores the convergence of mobile and ubiquitous computing with Web 2.0, in what is being termed as Ubiquitous Web. The aim of this research is to lower the barrier of developing and deploying context-aware applications in any location, especially uncontrolled environments. Mainly, our work consists on the spontaneous annotation by a community of users of objects, places or even people with web accessible multimedia content and services which can then be discovered and consumed by mobile users, whose contextual attributes match those of the annotations.

The outline of the paper is as follows. Section 2 explains the rationale upon which our work is based. Section 3 describes the architecture and characteristics of our main contribution, the Deusto Sentient Graffiti (DSG) system. Section 4 describes several scenarios where this infrastructure may be useful. Section 5 overviews some related work. Finally, section 6 concludes and suggests future work.

2 The need for for Ubiquitous Web

This paper aims to illustrate how the combination of the following four concepts may facilitate the materialization of the AmI vision:

- Current capabilities of mobile devices
- Web as a platform: Web 2.0 mash-ups
- Ubiquitous Web paradigm
- Social annotation of objects and places

In what follows each of these concepts is described, concluding with a rationale about the great potential opened by their combination, which justifies our research effort.

2.1 Capabilities of Mobile Devices

Current mobile devices are equipped with continuously increasing processing and storage capabilities, better and more varied communications mechanisms (Bluetooth [1], Wi-Fi, GPRS/UMTS) and increasingly capable multimedia capture and playback facilities. Besides, they are far more easily programmable [6][14][16] than ever before. Lastly, mobile devices equipped with Bluetooth GPS, built-in cameras, QR or circular barcode or RFID readers can be considered as *sentient* devices [11], since they can keep track of their context and are aware of what *smart objects* are in their whereabouts.

For us, a smart object is an everyday object (e.g. physical object or device) augmented with some accessible computational service or information (annotation). A *smart region* is a physical (GPS geodesic coordinates) or relative (within room A) location area to which a computational service or annotation has been associated which will be accessible to users physically or virtually within.

Current mobile devices' computing, sensing and communicating capabilities make them ideal candidates to act as intermediaries between us and the environment's smart object and region ecologies.

2.2 Web as a platform: Web 2.0 mash-ups

Web 2.0 [17] is a new buzzword coined to refer to the substantial innovation progress achieved by Web applications and portals in the last two years. For first time since the bursting of the dot-com bubble in the fall of 2001 the web industry has gathered a lot of interest. This is justified by the emergence of much more dynamic, responsive and user friendly web applications such as Google Maps or Flicr, backed by industry giants such as Google or Yahoo!.

The two most remarkable features of new Web 2.0 generation applications versus 1.0 ones are:

- *Read/Write Web*: the user stops being a passive subject, a consumer of data published by others, but he contributes continuously with new information (e.g. blogs, wikis)
- *Web as a platform*: the web can be seen not only as a huge collection of interlinked documents but as a set of web applications offering open APIs (REST or Web Services) that can be composed to create sophisticated applications combining data from diverse sources, namely *mash-up web applications*.

A key enabling technology for Web 2.0 is AJAX (Asynchronous JavaScript and XML). Through AJAX, page fragments rather than complete pages (in an asynchronous manner without interrupting user control) are sent after each user interaction. Consequently, the amount of data transferred between web servers and client applications is reduced dramatically, leading to the development of much more interactive and responsive browsing applications, ideal for the mobile domain.

From a research standpoint moving the new Web 2.0 paradigm from the desktop to mobile devices, i.e. moving towards *Mobility 2.0*, appears as an interesting challenge, which few so far have taken. In this work, we attempt to show the potential of mobile mash-ups applied to AmI.

2.3 Ubiquitous Web

The Ubiquitous Web (UW) defines a pervasive web infrastructure where all physical objects are resources accessible by URIs, providing information and services that enrich users' experiences in their physical context. In other words, UW means that the web is entering the real world, i.e. physical world entities are integrated into the world of web information and services.

The Web is a promising core infrastructure for ubiquitous computing and Ambient Intelligence because of its low barrier to entry, its device, language and service independence, its content centric model, its depth of features and its ubiquity. However, very few research works, later reviewed, have applied web-based infrastructure to Ambient Intelligence. Consequently, we deem paramount to adopt

open web technologies as core enabling infrastructure to extend the potential audience of AmI application development.

2.4 Social annotation of objects and places

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, and so on, using simple non hierarchical tags or keywords. A good example of a folksonomy is the del.icio.us website [4], where users can open an account, bookmark their favourite 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 [13] identifies the following strengths of folksonomies:

- *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*. 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 of entry*. Using folksonomies, which have a flat space of keywords, requires no special training.

On the other hand, Mathes [13] identifies the following limitations of folksonomies:

- *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).

An interesting extrapolation of social web tagging may be the concept of *GeoFolksonomies*, i.e. location-aware folksonomies or the result of social tagging geographic representations such as maps, plans, or any other topographic representation of an environment. The Tagzania service [19], mixing two Web 2.0-based services such as Google Maps and del.icio.us is a prime reference on this area.

The Tagzania approach although valid is limited to a single source of context (i.e. location). Thus, an even more interesting extrapolation of folksonomies would be what we term as *Context-Aware Folksonomies*, where everything (a location, an object or even a person) can be augmented with a description or service and some contextual attributes (location, identity, time). These attributes would represent the conditions upon which the virtual information associated to those objects or services were triggered.

Noticeably, the definition of Context-Aware Folksonomies may allow the efficient discovery, browsing and consumption of the web of resources pursued by Ubiquitous Web.

2.6 Rationale

This work aims to prove the promising potential opened by combining last generation mobile devices, the Web 2.0 platform, the Ubiquitous Web concept and social annotation in order to make reality the Ambient Intelligence vision. The following aspects serve as good indication of this conjecture:

- Current mobile devices capabilities make them ideal intermediaries between us and our environment.
- Mobile mash-ups running on mobile devices will allow anywhere at anytime discovery and consumption of AmI services.
- The web of resources proposed by UW suits perfectly to AmI, making the UW development interlinked to the extensive AmI adoption.
- Context-Aware Folksonomies provide efficient discovery, filtering, and consumption mechanisms for the web of resources of UW.

In conclusion, adding context-aware social annotations to physical objects is a plausible implementation approach for Ubiquitous Web, and, as side effect, Ambient Intelligence. Our view is that as long as there is some publicly accessible back-end infrastructure to register and publish the services associated to any environment (not only highly instrumented ones) the AmI vision can reach previously unconsidered spaces and scenarios.

In the rest of the paper we concentrate on describing the design and implementation of Deusto Sentient Graffiti (DSG), a system which attempts to prove this rationale.

3 Deusto Sentient Graffiti

Deusto Sentient Graffiti (DSG) enables mobile users to profit from the benefits of Ambient Intelligence in uncontrolled environments, only requiring in exchange, the participation in a community of users interested on publishing and consuming context-aware empowered annotations and services.

The main aim of DSG is allowing users to annotate objects and spatial regions with multimedia data or web services which are only made available to other users when those match the context attributes (location range, period of time, and so forth) previously assigned to the resources.

The following subsections describe the DSG system in detail. Firstly, the terminology used in DSG is explained. Secondly, the functionality of DSG is detailed. Thirdly, the internal architecture of DSG is reviewed. Fourthly, the motivation for creating an application enabling framework rather than a simple application is described. Finally, some details about the current implementation of DSG are offered.

3.1 DSG Concepts

Virtual Graffiti

A *virtual graffiti* can be thought of as a virtual post-it note in the form of an XML document which combines some content (multimedia presentation or web service) with some keywords summarising the content, and some contextual attributes (profile of creator, location, time interval and so on) which restrict who, when and where can those annotations be seen.

Graffiti Authoring & Bookmarking

Virtual Graffitis are edited through a PC web browser or, on the move, through the DSG Mobile application and then published on the Graffiti Repository. We currently support two types of graffiti content: multimedia presentations in SMIL format and URLs pointing to web service front-ends.

Before a graffiti is edited it has to be associated to a spatial region, using a physical (GPS) or logical (within a room) location, or an object, using its identity given by a barcode or a RFID tag.

Graffiti Filtering, Triggering and Querying

In order to prevent users from being overloaded with all the graffitis available at a location, at any time only those with contextual attributes that match users' current context are viewable.

Two components within DSG help on this graffiti filtering process: Graffiti Triggerer and Graffiti Querier.

The mission of the Graffiti Triggerer is to infer suitable graffitis for a user and filter out all the ones unlikely to be of interest. The Graffiti Querier allows for the on-demand context-aware interrogation of the Graffiti Repository.

Through those two components DSG supports both a) an event notification mechanism (PUSH-based approach) to which clients may register offered by the Graffiti Triggerer and b) a querying (PULL) mechanism provided by the Graffiti Querier.

Graffiti Consumption and Archiving

Sometimes it will be interesting to consume a graffiti only once whereas other times a fixed number of times or indefinitely. Besides, a graffiti may be valid forever or only for a certain period of time. DSG takes into account all these criteria in order to clean up expired or consumed graffitis. Those grafittis removed are archived in order to keep a historical of graffitis and allow past graffiti context retrieval.

WikiGraffitis

An interesting application of Web 2.0 principles to graffitis is what we have called *WikiGraffiti*, i.e. graffiti consumer participation on a graffiti by adding his personal

comments or additional multimedia content. This idea may be useful to encourage usage participation and the creation of communities of graffiti-ers.

Graffiti Domain

A *graffiti domain* is a set of user-set related keywords qualifying a graffiti category. Graffiti domains are interesting for graffiti filtering. For instance the graffiti domain `Deusto_University` may be associated to the graffiti qualifying keywords `university`, `engineering`, `bilbao`, `student`, `computer_science` and so on. A user registering his interest on viewing only `Deusto_University` domain's graffitis will automatically view only graffitis qualified by its set of associated keywords. Following this graffiti domain discussion, a user could create his own graffiti domains associated to his day profiles (at work, out for lunch, out from work, and so on).

3.2 DSG functionality

DSG presents a client/server architecture where users run a DSG client in either their mobile device or a computer's web browser, whilst a server-side component, namely DSG Server, stores, indexes and matches user annotations against user's current context published by DSG clients.

From a user's perspective, the *modus operandi* of Deusto Sentient Graffiti can be described as a two-fold process:

- *Graffiti annotation*. Users of DSG clients (mobile- or web browser-based) add annotations to objects or spatial regions consisting of:
  a. *Descriptions* (e.g. multimedia content or web service front-end URL)
  b. *Keywords*, describing annotated resources and enabling their classification and
  c. *Contextual attributes* which define the conditions to be met by consumers of those annotations. Some of those attributes will be set automatically by the DSG client (who created the annotation, where and when) whilst others will be explicitly set by the user (location range where the tag should be viewed, who can see it, when and for how long, and so on).
- *Graffiti discovery and consumption*. Users equipped with a mobile device or remotely through a web browser running the DSG client, move (physically or virtually) through an annotated (virtually graffiti-ed) environment, browse and consume the available annotations matching the user's current context, profile and preferences. This interaction may take place in an explicit, i.e. the user interacts with the application requesting available annotations, or implicit manner, i.e. the system alerts the user when new annotations are available corresponding to his current contextual attributes.

From a system's point of view, DSG can be seen as both a *Context-Aware Folksonomy* and a *Context-Aware Mobile Mash-up*. As a Context-Aware Folksonomy, DSG establishes a spontaneous classification of the objects and spatial regions annotated and their relationships. Thus, it is possible to link annotations of resources sharing all or a subset of keywords. In other words the system itself can autonomously define graffiti domains.

As a Context-Aware Mash-up, the mobile and web-based DSG clients combine geographical information in the form of maps (e.g. obtained from GoogleMaps) and the DSG back-end supplied descriptions. These mobile mash-up clients provide users equipped with a last generation mobile device or a web browser with the graffiti annotation, discovery and interaction functionality earlier mentioned.

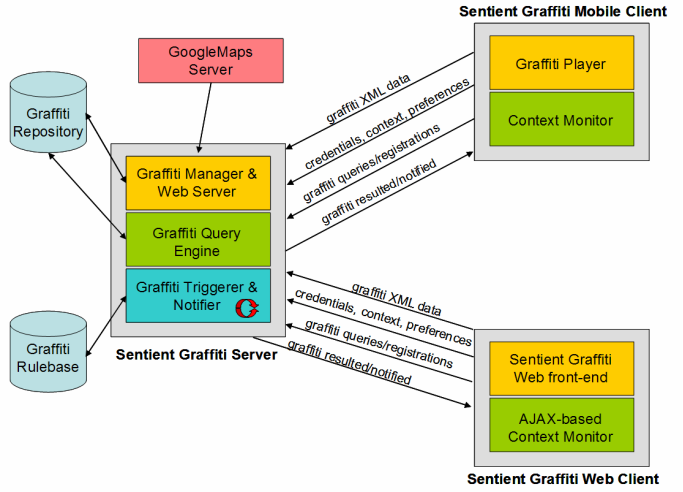

Fig. 1. DSG Architecture

3.3 DSG Architecture

The following components compose the Deusto Sentient Graffiti client/server architecture, shown in Fig. 1:

- *Graffiti Manager & Web Server*: it manages all the virtual graffitis published, including their content and metadata (keywords and contextual attributes) stored in a relational database, termed Graffiti Repository.
- *Graffiti Triggerer and Notifier*: an ECA rule based [9] inference engine at the back-end populates its knowledge base with contextual attribute changes received from users' DSG clients, and infers sets of active annotations which have to be notified to those users' DSG clients, where they are depicted. The annotation inference is supported by a set of generic rules stored in a rule base which embodies the intelligence of DSG. The separation of the intelligence of the system into a set of rules is a very flexible approach to continuously tune the behaviour of the system. Those rules not only determine what new annotations need to be transmitted to a DSG client but they are also in charge of garbage collecting expired annotations (those consumed a previously specified number of times or whose living period has expired). This component enables a DSG client to operate on a PUSH manner, without user intervention once a session between the client and the triggerer has been established.
- *Graffiti Querier*: this back-end component is responsible of processing context-aware annotation retrieval queries from DSG clients by consulting the Graffiti

Repository. This component enables a DSG client to operate on a PULL manner, communicating with the back-end only under user's explicit command.

- *Context -Capture and -Change Monitors*: run on a mobile device or web browser they monitor significant changes on the user's context which they either cache for transmission on annotation queries or feed to the Graffiti Triggerer if operating in PUSH manner. One of the main goals of this component is to reduce the amount of data transferred between the mobile application and the DSG server-side in order to reduce communication costs and maximize the interactivity of the system. This module in the web browser only monitors virtual location changes, whereas in the mobile device is capable of recognizing TRIP [10] codes and tracking location changes through GPS in outdoor environments. We are currently trying to add support to this module for other indoors applicable location systems such as Ubisense, RFID and Place Lab [8].
- *Graffiti Player or Web Front-end*: displays virtual graffitis on a user's device, which may be a PC (web application on a web browser, displaying a map combined with markers indicating context-retrieved graffitis) or mobile device (Java ME o Compact.NET clients, with both a map view or a list of available graffitis at a certain location). Apart from playing graffitis (rendering their multimedia content or a web service front-end) it also enables creation, deletion and edition of graffitis.

The modules composing Deusto Sentient Graffiti system may all be running on a mobile device. However, more logically only the Context-capture and –change Monitors and the Graffiti Player will run on the mobile device. The user's mobile device will continuously or periodically connect to the DSG server via a wireless link (Wi-Fi or GPRS/UMTS) in order to undertake context-based retrieval of graffitis.

As previously mentioned the context-capture and -change monitor will play a significant role trying to reduce the communication costs. In the case of using a public access network such as GPRS/UMTS is recommended to use a PULL-based mechanism.

3.4 DSG Infrastructure

Noticeably, our purpose is not only to design and develop the DSG system as an example of a practical Ubiquitous Web application approaching the AmI vision. More importantly, we attempt to provide with DSG a framework useful to construct real-life context-aware applications (e.g. the ones illustrated in the following section). Those applications will present the following functional requirements addressed by DSG:

- Model every physical object or spatial region whose information or services may be consumed.
- Make available to users only the annotations associated to surrounding resources available under their current contextual conditions or desired filtering requirements.
- Facilitate explicit user-controlled interaction with the smart object and spatial regions encountered by a mobile user, both in a PUSH and PULL manner.

3.5 DSG Implementation

Fig. 2 shows the GraffitiXML syntax used to specify the contents of a graffiti, which is made of a `head` and a `body` part. The `head` consists of some general attributes (`id`, `title` and `description`), a set of `keywords` identifying the purpose of the graffiti and some contextual attributes. The contextual attributes are divided into `implicit`, i.e. automatically set by graffiti clients (mobile or web-based), and `explicit`, i.e. set by the graffiti creator. Finally, the `body` contains either a multimedia file in SMIL [21] format or the URL of a web service.

```
<graffiti>
  <head>
    <general>
      <id><!-- unique ID --></id>
      <title><!-- graffiti title --></title>
      <description><!-- description --></description>
    </general>
    <keywords><!-- qualifying keywords --></keywords>
    <context-attributes>
      <implicit>
        <who></who>
        <when><when>
        <where type="gps|TRIP"><!-- coord. or IDs --
></where>
      </implicit>
      <explicit>
        <who><!-- who can see the graffitis --></who>
        <within><!-- viewing location range --></within>
        <when><!-- hour range --></when>
        <during><!-- period of availability --></during>
        <times><!-- how many times --></times>
      </explicit>
    </context-attributes>
  </head>
  <body type="SMIL | WebService">
    <!-- SMIL file content or web service url -->
  </body>
</graffiti>
```

Fig. 2. Graffiti XML representation

A Java implementation of the DSG server-side has been completed which runs on a Tomcat application server and uses the frameworks Tapestry, Spring and Hibernate, the Java expert system shell (Jess) and the database backend MySQL.

A web-based front-end client for DSG has also been completed. Fig. 3 shows the steps necessary to construct through this interface a graffiti and how it is then displayed in the web front-end. Fig. 4 shows how to create a Graffiti Domain and then use it for graffiti filtering.

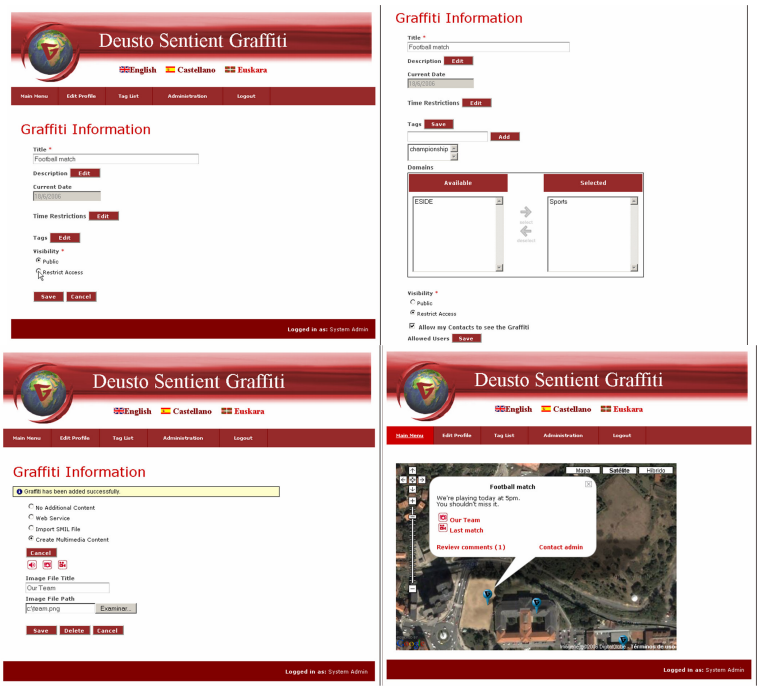

Fig. 3. Creating a Graffiti in DSG

A Java ME DSG client is currently being completed which will enable the creation, search, discovery and play-back of graffitis from mobile phones. Once this task is completed, DSG will truly be a mobile mash-up.

Fig. 4. Creating a Graffiti Domain and Filtering

4 DSG Scenarios

In this section, some context-aware application examples are described which show the potential use of the DSG infrastructure. The applications presented are categorised in two main groups: a) those using graffitis belonging to controlled domains and publicly available and b) graffitis assigned to spontaneous domains or keywords, only known by a restricted community of users.

Public organisations or companies using DSG infrastructure can clearly profit from the use of regulated *Graffiti Domains*. Some possible examples are:

- *Context-Aware City Tours*: the tourist board of a city may associate virtual graffitis with multimedia content in those spatial regions of the city which are of special interest for tourists. In order to enable the tourists to focus only on tourism-related graffitis and not being overloaded by other parties graffitis, the user may set a filtering request (as shown in Fig. 4) to only accept graffitis associated to a certain domain (e.g. `Bilbao_tourism`). Besides, the Web 2.0 nature of DSG would enable tourists visiting those premises to add comments on the graffiti. Thus, DSG would enable the creation of a collaborative context-aware tour guide.
- *Context-Aware Conference*: attendees to a conference may be guided to the conference premises and offered conference services by means of a set of graffitis deployed both in the surroundings and in the conference hall. Again, attendees may filter spurious unrelated tags by setting their graffiti filtering to only accept graffitis belonging to the Graffiti domain for the conference, e.g. `UBICOMP06`. The validity of the graffitis would expire once the conference is finished. Some of the graffitis could serve as a hook to retrieve attendees' feedback, by enabling graffiti visitor commentaries.
- *Context-Aware Publicity*: companies may wish to create a publicity campaign by which the first users visiting certain graffitis distributed through certain areas in a city get some gifts tokens. In this case, the capacity of a graffiti being consumed after a certain number of visits could be exploited.

On the other hand, the applications where graffitis associated to unregulated domains make more sense are:

- *Context-Aware Friend Meetings*: friends joining for a drink in a pub may leave a graffiti outside the previously visited pub so that late coming friends may notice his friends have moved meanwhile to another pub or even allowing contacting them. The published graffitis would only be made visible for a certain group of users (missing friends).
- *Context-Aware Blogs*: a pub may create a blog consisting of several graffitis with opinions, pictures or suggestions of customers who have visited the pub. The same idea could be applied in classrooms or offices, to create blogs summarizing their daily activities.

5 Related Work

Several related projects, such as our previous work on the EMI2lets platform [12], have focused on adding context-aware discovery and interaction within highly

sophisticated controlled environments, whereas this work attempts to lower the barrier of deploying simple context-aware applications anywhere, even uncontrolled environments.

Tagzania [19] is a geofolksonomy and a mash-up which combines social tagging in a del.icio.us style with geographical information coming from GoogleMaps. With the help of its web front-end, users may associate tags to planet locations and then browse through them. Tagzania presents three main limitations compared to DSG:

- A marker assigned to a physical location is associated to a description (text, image) without including any additional contextual attributes which limit who can see a tag and when.
- A user can only edit, discover and browse tags through a PC browser. No support for mobile devices is allowed. Therefore, Tagzania cannot be catalogued as a mobile ubiquitous web application.
- The internal design of Tagzania may lead to information overload, since everybody sees every tag at any time, without taking into consideration the user preferences, profiles and context (e.g. current location, list of contacts).

The Socialight project [18] approaches more to the definition of Ubiquitous Web application. It enables sharing location-based notes, termed StickyShadow, pictures and sounds from the web and a phone. A StickyShadow is made up of media, such as text and a picture, and information about who can see it and when and where that note is available. The full set of attributes associated to a StickyShadow is:

- Title
- Message
- Note and media (text, image, sound or video),
- Allowed viewers (only me, contacts, all users)
- Physical location (GPS coordinates, postcode, and viewing range)
- Expiration period and
- Tags to index and classify notes into a folksonomy.

Any time a user running on his mobile device the Socialight system steps on a StickyShadow, Socialight notifies him. As the user phone buzzes, it will display the media, along with some information about the person who set it. From there, the user may instantly respond, leave his own StickyShadow or just move on. In essence, Socialight merges the fields of mobile social networks and geofolksonomies. It can be catalogued as a Mobility 2.0 and UW-compliant application.

The DSG project is conceived as a refinement of Socialight. It aims to tag the planet not only with location- but more general context-based annotations, which are triggered only when a user's mobile device matches some contextual attributes (location, period, identity of user, and so on). DSG distinguishes from Socialight in the following aspects:

- Associates to objects not only multimedia content but also services, with contextual metadata enabling Context-Based Execution of Services. It is not only limited to presentation of data.
- Mixes social tags, location and context information, user profile and preferences. A user may register sophisticated matching requests during a period. For example, through graffiti domain mechanisms.

- Includes a flexible and sophisticated inference engine on the back-end adding the real intelligence to the whole system. This means that the client application is not only restrained to the use of an expensive PULL-based approach to continuously retrieve associated annotations.
- Provides map views of a user current location enriched with markers denoting context-based retrieved associated annotations.
- Aims both indoor and outdoor environments, since its DSG client enables a user to discover annotations associated not only to a physical outdoor GPS location but also to barcode tags (TRIP-based) and soon RFID.
- DSG does not only allow a user to respond to the author of a graffiti but also to add new comments or content to them through the WikiGraffiti concept.
- Eventually, DSG is thought to progress towards a Semantic Ontology which will enable rich relationships to be defined among annotations, annotators and readers, by applying sophisticated matching algorithms.

Both our DSG system and Socialight are inspired by the earlier stick-e notes project [2]. This project defined an infrastructure enabling the edition, discovery and navigation of virtual context-aware post-it notes. 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 post-it author, the location where the tag was created, the time interval in which that tag should be available, and so on.

The concept of Ubiquitous Web was first considered on W3C Workshop on the Ubiquitous celebrated on March 2006 [20]. However, before this workshop initiative, other researchers had already considered the convergence of web-related technologies and ubiquitous computing. A fine example of this was the CoolTown project [7]. 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.

DSG can be understood as a mixture of the stick-e notes and Cooltown projects. It uses the same virtual post-it metaphor as stick-e notes, but it is based on web standards like Cooltown, although it uses a Web 2.0 approach rather than a 1.0 approach as Cooltown. Neither Cooltown nor stick-e note make use of folksonomies to classify smart objects and regions and enable keyword-based filtered discovery.

6 Conclusion and further work

We deem that Ubiquitous Web should lead us towards the creation of mobile social software communities, where users both real and virtual may discover based on their

current context everyday physical objects and regions augmented with virtual annotations, with which they can interact.

The current pre-semantic web incarnation of Deusto Sentient Graffiti enables the edition, discovery, filtering and interaction of annotations placed anywhere in the campus of the University of Deusto. Initially, we are restricting its operation to the Deusto University campus, rather than the whole world, for two reasons:

1. Asses scalability issues that may arise once the system is made available for any user anywhere, and
2. Evaluate the role this system may play on constituting a mobile context-aware social network of our students sharing their knowledge as a cloud of annotations, in a similar manner to the Active Campus [5] project.

In future work, we want to model graffitis, authors and consumers in an ontology to check whether through a semantic model we can infer further associations between entities and users.

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References

1. Bluetooth Specification version 1.1, http://www.bluetooth.com, (2006)
2. Brown, P.J.: Triggering information by context. Personal Technologies, Vol. 2, No. 1, (1998) 1-9.
3. Definition of 'Folksonomy', http://en.wikipedia.org/wiki/Folksonomy, (2006)
4. Del.icio.us website, http://del.icio.us, (2006).
5. Griswold W.G., Shanahan P., Brown S.W., Boyer R., Ratto M., Shapiro R.B., Truong T.M.. ActiveCampus: Experiments in Community-Oriented Ubiquitous Computing. IEEE Computer, vol. 37, no. 10, (2004), 73-81.
6. Java ME - Micro App Development Made Easy, http://java.sun.com/javame/, Sun Microsystems, Inc, (2006)
7. Kindberg. T., Barton, J., Morgan, J. et al.: People, Places, Things: Web Presence for the Real World. In proceedings WMCSA2000. In MONET Vol. 7, No. 5 (2002).
8. LaMarca A., Chawathe Y., Consolvo S., Hightower J., Smith I., Scott J., Sohn T., Howard J., Hughes J., Potter F., Tabert J., Powledge P., Borriello G. and Schilit B. .In proceedings of Pervasive 2005, Munich, Germany.
9. López-de-Ipiña D.: An ECA Rule-Matching Service for Simpler Development of Reactive Applications, published as a supplement to the Proceedings of Middleware 2001 at IEEE Distributed Systems Online, Vol. 2, No. 7, (2001).
10. López de Ipiña D., Mendonça P. and Hopper A., TRIP: a Low-cost Vision-based Location System for Ubiquitous Computing, in Personal and Ubiquitous Computing, Vol. 6, No. 3, (2002) 206-219.

11. López-de-Ipiña D., Vázquez I. and Sainz D. Interacting with our Environment through Sentient Mobile Phones. Proceedings of IWUC-2005, ISBN 972-8865-24-4, (2005), 19-28.
12. López-de-Ipiña D., Vázquez J.I., et al., EMI2lets: a Reflective Framework for EnablingAmI, Journal of Universal Computer Science (J.UCS), Vol. 12, No. 3, (2006), 297-314
13. Mathes, A. Folksonomies - Cooperative Classification and Communication Through Shared Metadata, http://www.adammathes.com/academic/ computer-mediated-communication/ folksonomies.html, (2004).
14. Mobile Developer Center, http://msdn.microsoft.com/mobility/, Microsoft Coorporation, (2006).
15. Shadbolt N.: Ambient Intelligence. IEEE Intelligent Systems, Vol. 2, No.3, (2003).
16. Symbian OS – the mobile operating system, http://www.symbian.com/, Symbian Ltd., (2006).
17. O'Reilly T. What Is Web 2.0 -- Design Patterns and Business Models for the Next Generation of Software. http://www.oreillynet.com/pub/a/oreilly/tim/news/2005/09/30/what-is-web-20.html, (2005).
18. Socialight project website, http://socialight.com/home, (2006).
19. Tagzania – tagging the planet, http://www.tagzania.com/, (2006).
20. W3C Workshop on the Ubiquitous Web, http://www.w3.org/2005/10/ubiweb-workshop-cfp.html, (2006).
21. W3C, Synchronized Multimedia, SMIL Home Site, http://www.w3.org/AudioVideo/, (2006).
22. Place Lab: Device Positioning Using Radio Beacons in the Wild.