User-Aware Semantic Location Models for Service Provision

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***Abstract*—Thus far, mobile devices have been used to consume services, rather than to provide and consume (*prosume*) them. Besides, user localization through mobile phones is usually restricted to GPS outdoors or coarse cell triangulation, otherwise. This paper describes the MUGGES mobile location-aware service prosuming platform, which enables service provisioning directly from mobile phones and integrates the outputs of heterogeneous location methods into a consistent, homogeneous and semantic location model. Such platform has been trialled through four types of location-aware services. The results obtained suggest that the prosumer approach has potential for wide deployment, providing some limitations of current mobile technology are first overcome.**

Keywords: Location-aware, micro-service, middleware, mobile computing, ontology

I. INTRODUCTION

Social services such as Facebook, YouTube or Twitter have empowered users by making them not only consumers of information but also producers, i.e. converting them into data prosumers. This trend is now moving to mobile social services (e.g. Foursquare or Google Hot Pot), which offer a more natural ubiquitous way of social interaction – from a user's mobile device. Interestingly, most current mobile devices incorporate Global Navigation Satellite Systems (GNSS) technology, such as GPS, making location-based mobile social services a very clear opportunity for business innovation. This is due to the fact that location is considered as a key context attribute for more optimal service and data filtering and recommendation in mobile domains [1][2].

The Mobile User Generated Geo Services (MUGGES) project [3], funded by the European Commission's 7th Framework Programme, goes one step further from current mobile location-based services (LBS) by providing location-annotated services and their contents directly from a user's mobile device, i.e. the device evolves to be a server. Thus, mobile users become service *prosumers*, i.e. producers, providers, and consumers of services and associated contents from mobile terminals.

Furthermore, MUGGES enhances current mobile devices' location management by complementing GNSS-based technology with alternative location technologies (e.g. Cell tagging, Wi-Fi wardriving or even QR codes encoding location descriptions) better suited for indoor environments. Consequently, a key contribution of this work is the definition of a new location modelling concept, namely MUGGES location, which seamlessly combines physical, symbolic and semantic descriptions of a place, in order to improve the process of matching services to users. Notably, this model is fed with user's mobility status hints that help refining the service searching and selection process.

The paper is structured as follows. First, previous work related to the MUGGES platform is discussed and compared to our solution. Secondly, the devised MUGGES platform is described. Thirdly, the user-aware semantics-empowered MUGGES Location Management System (LMS) is analysed. Fourthly, the behaviour of users while providing and consuming location-aware micro-services from their own mobile devices, as experienced in a real trial, is described. Finally, the lessons learned during the trial are summarised and planned further work is described.

II. RELATED WORK

Lately the research community has experienced an upsurge of significant developments in mobile location-based services (LBS). For example, Foursquare [4] is a location-based social networking application which allows registered users to connect with friends and update their location. Users can read and add tips to venues which will serve as advice for things to do, see or eat. This way, users can meet their friends and discover interesting places and activities around them, which they would have missed otherwise. Similar services to Foursquare include Yelp [5], Whrll [6], Plazes [7], Google Latitude [8] or Loopt [9].

The mentioned LBSs are all *final services* since they do not allow users to create new kinds of services. Users are allowed to create new content but they cannot define any new functionality on top of them. This is possible in MUGGES, which is designed as a service provisioning platform. Furthermore, the underlying location model in these services is restricted to points of interest, by means of coordinates, or addresses on a map, e.g. via the Google Maps API [10], which, at this point, does not support semantic relationships among locations.

On the other hand, several proposals have been described oriented towards providing *service platforms for LBS*. As such, the Service Platform for Innovative Communication Environment (SPICE) project investigates, prototypes, and evaluates an architecture and framework for rapid creation and deployment of intelligent and personalized mobile communications and information services [11]. Similarly, m:Ciudad [12] embodies a set of mobile tools and a service platform to allow users to create their own mobile micro-services. These micro-services are created, consumed and provided directly on their mobile devices. Both platforms allow users to create their own services. However, none of them incorporates a location management system to enable users to create location tagged services which can be searched and selected based on location restrictions.

Finally, several authors have tackled the complexity of modelling location information for LBS. Becker and Dürr [13] propose the use of hybrid location models for ubiquitous environments. Jiang and Steenkiste [14] introduce the idea of a virtual location as an abstract notion of different location types. This facilitates easier querying within a homogeneous location model. Likewise, Li and Cao [15] present a location ontology to enable reasoning about containment relations between locations. Standardization efforts led by the Java community such as JSR-179[16] have attempted to uniformly model location as an aggregate of syntactic and physical location or to even support heterogeneous location providers. MUGGES shares similar heterogeneous location information management goals as those proposals but it distinguishes by considering not only the current user location as a filter but also the user's mobility context. Furthermore, it emphasizes the importance of trying to interpret and reason upon a third aspect which may characterize location data, its semantic representation.

III. The MUGGES Platform

The MUGGES project provides users of mobile devices with tools and P2P (peer-to-peer) infrastructure to allow them to create mobile location-based micro-services on the go, turning the mobile device not only in a micro-service *player* but also into a *server*.

A. Mugglets: MUGGES-enabled applications

Within the MUGGES project, micro-services are coined as mugglets. They are small and independent location-based social services hosted in the mobile terminal and provided directly from a mobile device to another mobile terminal. The following four mugglet types have been designed and tested by real users (see Figure 7):

- *MUGGES Note*. This mugglet allows publishing short messages with a photo, both attached to a specific location. Other users can then retrieve these messages (see Figure 7a and Figure 7b).
- *MUGGES Journal*. The main objective of this mugglet is to maintain a user Journal or blog. This mugglet represents a set of semantically related MUGGES Notes maintained by a single author and ordered by date. Each note has its own location (see Figure 7c).
- *MUGGES Trail*. This mugglet is an application which allows users to define routes with information about the places on them by adding a sequence of MUGGES Notes (a starting point, intermediate points and a goal). This mugglet type allows users to see the directions from their current location to the next point on the route, with the aim of correctly guiding them to the end of the route (See Figure 7d).
- *MUGGES Race*. This mugglet is made for runners allowing them to follow a predefined route and compete with others in an asynchronous manner. Users must reach specific checkpoints to get to the goal and complete the race. The total time is measured and recorded in the service (See Figure 7e). Each point of the race is considered and implemented as a MUGGES Note. MUGGES Peer-to-Peer Architecture

B. The MUGGES Peer-to-Peer Architecture

As shown in Figure 1, the MUGGES platform is modelled as a triangle where centralised server infrastructure facilitates the creation of direct peer-to-peer (P2P) connections between producers and consumers. The operation mode is as follows. Firstly, the service provider creates a given service (mugglet), and publishes it through the service infrastructure. Secondly, a published mugglet can be searched for and found by other MUGGES users. Thirdly, users consume a mugglet after retrieving the connection details of such mugglet from the server infrastructure. Finally, the consumer device renders the mark-up corresponding to the mugglet front-end. Thus, it allows the service consumption and direct communication between consumer and provider devices. Such centralised peer-to-peer architecture entails several advantages for the user:

- *Service provisioning can be done instantly*, without needing for cumbersome uploads to an intermediate Internet platform.
- *Users always maintain full control* over their services and own content and can withdraw them at anytime.

On the mobile client-side, MUGGES provides two mobile applications, developed on Java ME, to manage mugglets: 1) the *creation kit* which guides the user through an intuitive mugglet creation process (see Figure 2) and 2) the *execution platform* which handles the installation of mugglets, their execution and grants access to the mobile phone capabilities (e.g. the embedded GPS or camera devices). Notice that direct data communication among mobile devices is performed over sockets through a custom-built protocol that seeks data flow optimization. Note that the mobile operator supporting the project provided SIM cards for the trials that were enabled for socket communication on user-defined ports.

On the server-side, different software components assure the MUGGES system's functionality. The central *Controller* component acts as a REST gateway for the client-side to access the server infrastructure. The *Warehouse* component hosts a storage system for mugglets and their related templates. It allows users to search for existing mugglets or available templates from which new mugglets can be instantiated based on keywords, template category and location. Since mobile devices may use different positioning technologies, a *Location Server* supports the translation between different location concepts. Finally the *User Management and Accounting* Servers provide user and community profile management functions and also record information required for billing or user traceability purposes.

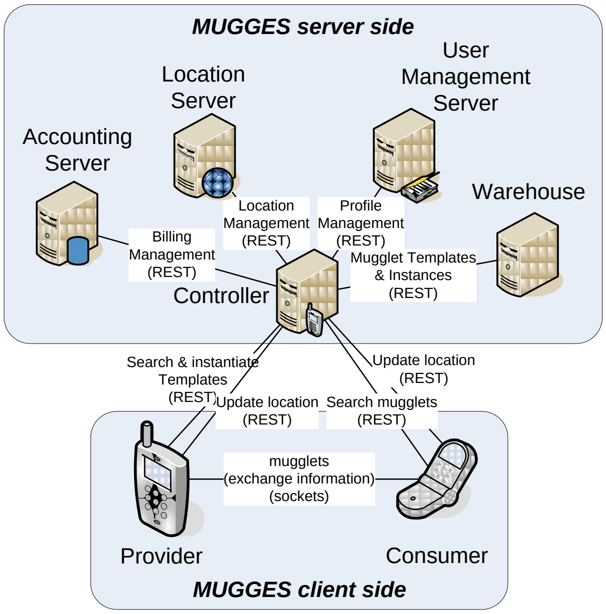

Figure 1. The PROSUMER triangle.

Figure 2. Mugglet creation screenshots.

The SOA architecture devised is implemented by means of the Restlet framework on the server-side. The client-side running on mobile devices communicates following the RESTful approach via the HTTP protocol with the server-side. The standard socket support available in Java ME was used for this purpose.

IV. A Hybrid User-aware LMS

The MUGGES platform envisages user-generated services (mugglets) annotated with *semantic location* information, so that their search-ability and filtering can be performed under user-provided location restrictions.

The *Hybrid and Semantic Location Management Server (HS-LMS)* component is designed to cope with the translation and interpretation of location data supplied from heterogeneous location sources such as GPS (and eventually Galileo), RFID, Wi-Fi base station or Cell Ids. Having alternative capture methods, supported by the MUGGES mobile-side execution platform (GPS, Cell-ID location and location encoding QR code recognition), ensures that different users and mugglets can cooperate under stringent location-aware restrictions. Another important design objective is that it is conceived to integrate location models and instance data from third party map provides to enable more powerful location interpretations.

A. *The MUGGES Location concept*

MUGGES aims to support heterogeneous location capture and specification methods. As a result, the concept of a virtual location, namely *MUGGES Location (ML)*, is introduced. Such concept aims to enable correlating technical and human understandable location specifications. An ML is composed of the following three facets:

- *Physical*: A point in a reference system (might be accompanied by a geometric bounding shape). In geographic systems this is typically expressed through latitude, longitude and altitude coordinates, e.g. in the World Geodetic System [17] used by GPS receivers. For instance, the city of Bilbao is located at latitude: 43°15'25", longitude: -2°55'24", altitude: 19m.
- *Symbolic*: A human-readable and understandable textual description of a location, e.g. "University of Deusto, Bilbao" or "United Kingdom".
- *Semantic*: A machine-understandable location expression upon which location-related inferences can be undertaken, e.g. the University of Deusto lies in the city of Bilbao, which in turn is located in the Basque Country, in Spain and so on.

The most comprehensible location type to the user is the symbolic one, whereas to show the location on a map, physical locations are needed. However, to enable sophisticated location search, semantic links among the locations to reason about their relationships are needed [14][15]. Conventionally, only one of those facets is specified while searching for mugglets or reasoning about locations relationships between users and mugglets. It is the HS-LMS's duty to translate, if possible, among the different instances of location specifications so as to fulfil the requested location-related tasks.

For example, the ML associated to the city of Bilbao contains information about its physical location (latitude, longitude, and altitude), its symbolic description ("Bilbao, Spain") and links to other MLs (the city of Bilbao is a child of the province of Biscay). This information is not usually complete, e.g. an ML might lack semantic links to other MLs or its coordinates might be unknown. One of the mains tasks of the HS-LMS is to generate, maintain and constantly update a coherent location model.

B. *Location Ontology*

In addition to defining a new location ontology, the MUGGES HS-LMS resorts to ontologies accounting for different kinds of location relations, e.g. geographic, political or administrative relations as shown in Figure 3, which can be summarized as follows:

- *Geographic*: Geographic relations, e.g. "Campus of Bilbao" is contained in "Deusto" (a suburb of Bilbao)
- *Political*: political entities, such as Spain, France, Germany or the EU, which is parent of all of the former countries.
- *Administrative*: Relations between administrative, not necessarily physical, entities, e.g. the Google company

which comprises several centres distributed around the world.

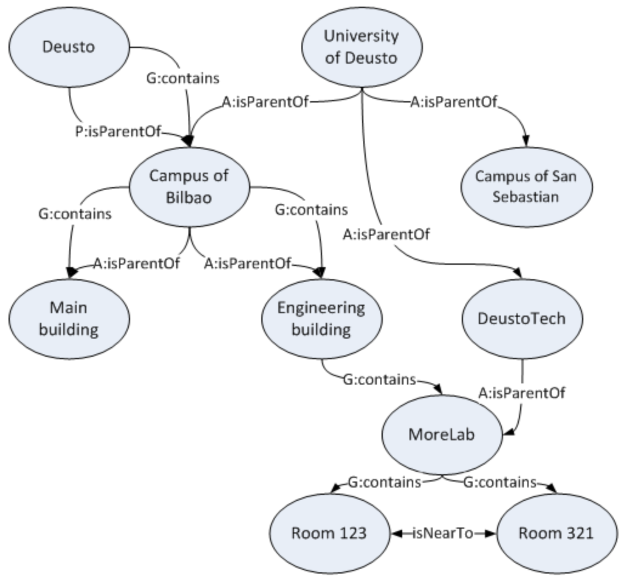

Figure 3. Ontologies used in MUGGES.

The instance data of the core MUGGES ontology exemplified in Figure 3 illustrates the advantages of incorporating several types of ontologies into the MUGGES semantic location model. We directly infer from the graph that the "Engineering building" is both geographically located on the "Campus of Bilbao" and administered by the latter. Moreover, through ontology reasoning we can infer that 1) the "Campus of Bilbao" is located in "Deusto" (a district of Bilbao), by using the Geographic ontology (G); 2) it belongs to the administrative entity "University of Deusto" by using the Administrative ontology (A); and 3) it contains the "Engineering building" (G and A), and thus, bearing in mind the transitive nature of the G:contains property, it can be inferred that it contains the "MOREIab" research group (G) but it does not administratively manage it, since this is connected (A) to the "DeustoTech" branch of the "University of Deusto".

These three domain-independent location categories have been chosen as basis for our ontology, having been fed manually with significant instance data associated to the location of our trials (e.g. Bilbao, SPAIN). This ontology could be enhanced with semantic *location overlays*. For example, a tourism-specific ontology extension could arrange MUGGES Locations into a graph of "interesting touristy places" where a connection from one ML to another could be set taking into account either its physical nearness or tourism-related affinity. Furthermore, new location data linked to existing instance data and corresponding to points of interest for end-users could also be inserted, aided by the mobile user interface, during mugglet instantiation.

C. 3rd Party Ontology Integration

Although instance data for areas of special interest in MUGGES deployment have been manually created (e.g. the MUGGES trials), as already mentioned, it is not feasible and even convenient to create all instance data manually. Hence, we have made use of third party location information systems. We have limited our external sources to GeoNames and Google Maps, but other location services could be easily incorporated, e.g. Yahoo Maps and OpenStreetMap.

GeoNames offers a geographic location ontology with instance data suitable to be mapped and feed our own geographic ontology. Google Maps on the other hand, does not keep semantic relations among locations. For instance, the "University of Deusto" and "Universidad de Deusto" location specifications might be interpreted as two different locations.

The HS-LMS's duty is to merge the locations of both providers, so that it identifies equivalent locations and inserts them correctly into the ontology under the same entry. Our simple, yet effective, merging algorithm (see Figure 4) is based on the idea of establishing different hierarchy levels of locations. These are in detail from lowest to highest area: room, spot (e.g. a building), street address, street name, street intersection, postcode, suburb, city (e.g. city of Bilbao), administrative level 1 (e.g. district of Bilbao), administrative level 2 (e.g. Biscay), administrative level 3 (e.g. Basque Country), country (e.g. Spain), continent (e.g. Europe). We chose this classification scheme to create a common denominator among similar schemes offered by GeoNames, Google Maps, and Yahoo Maps. This classification is sufficient for the applications envisioned in MUGGES, and more importantly, we can build on instance data from external services by mapping them to our hierarchy level. Apart from geographic information, the classification also contains political information, like the administration level or the postcode. We can also use this location information for both the geographical and political ontology.

The location model grows according to its usage since MLs are created the first time they are needed. Clearly, the algorithm does not link every location correctly, e.g. if the names returned by GeoNames do not match the name returned by Google Maps. In this case, two MLs of the same real-world location are created. This issue may be resolved by requesting user collaboration in aligning MLs which are actual aliases of a given location. We may also allow users to introduce missing locations that they would like to use for mugglets through a location specification wizard. These are ideas about future enhancements of our system.

D. User-Awareness in HS-LMS

The correlation between locations and relevant services or contents is complex. Questions like what type of location technology is the most appropriate, or how location-related functionality, e.g. nearby locations, are to be interpreted are non-trivial and often depend on the current user situation.

The MUGGES location ontology and concept allow us to add capabilities to the LMS enabling automatic adaptations on the location view depending on the mobility status. For example, if the user is walking, the location granularity has to be finer than when the user is driving a car or going by train. Next, we describe three functions which better justify the need for making LMS user mobility status aware:

- *Detection of appropriate location technology*: If a user looses GPS reception, depending on the user's mobility status, two alternatives emerge. In the case that a user enters a building, the last known GPS position is better than the cell-ID because a building size is usually smaller than a cell size. In the case that a user enters a train, it is better to use the cell-ID as an alternative location because of the train's high speed.
- *Searching for "nearby" locations*: The meaning of "closeness" depends on the dimensions of the parent location, what "nearby" means to the individual user, and the user's current mobility status (e.g. walking, going by car, etc.). Using GPS, nearby usually relates to locations on the same hierarchy level. Results are retrieved using the geographical ontology ("real" nearby feature) and can be ordered subsequently by other ontologies (e.g. administrative). When applying cell-ID nearby converts to "contains" as the cell-ID area can be assumed to be rather big.
- *Automatic adaption of location hierarchy level based on number of results*. In the case when too many or no results are retrieved (based on a threshold for max and min), the LMS should automatically move up and down the location hierarchy until a sufficient amount of results can be retrieved. For example, if no results for location "Room 123" are given, then the location manager would go up in the geographic hierarchy, repeating the search on the parent location and checking if there were enough results, and subsequently would repeat the process until a sufficient number of results are returned or the root element is reached.

V. TRIALLING LBS SERVICES

A functional and technical evaluation of the MUGGES system has been carried out through a user trial hosted in Bilbao (northern Spain). The base scenario has been:

- 17 users (computer science students aging 20-25) equipped with Nokia 5800 XpressMusic touch screen smart phones with a 3G/3.5G data connectivity powered with MUGGES components and GNSS receiver.
- 10 hot areas for interaction at the campus of the University of Deusto as indoor locations, where points of interest have been tagged with QR-codes encoding MUGGES location URIs.
- Specific parts of Bilbao limited by geographic coordinates as outdoor location.
- 4 deployed social LBS applications (see Figure 7) that promote location-based interactions among different user types.

The trial was started with a 2 hour kick-off introduction to the MUGGES functionality and the distribution of specific scenarios. During the trial, users were also encouraged to test the application freely elsewhere in order to gain as much technical and functional information as possible. The execution of each task by trial users generated an event with location information which enabled us to visualize the MUGGES activities of trial users on maps. Additionally, after the two-week trial, information about their motives were collected with surveys and focus interviews.

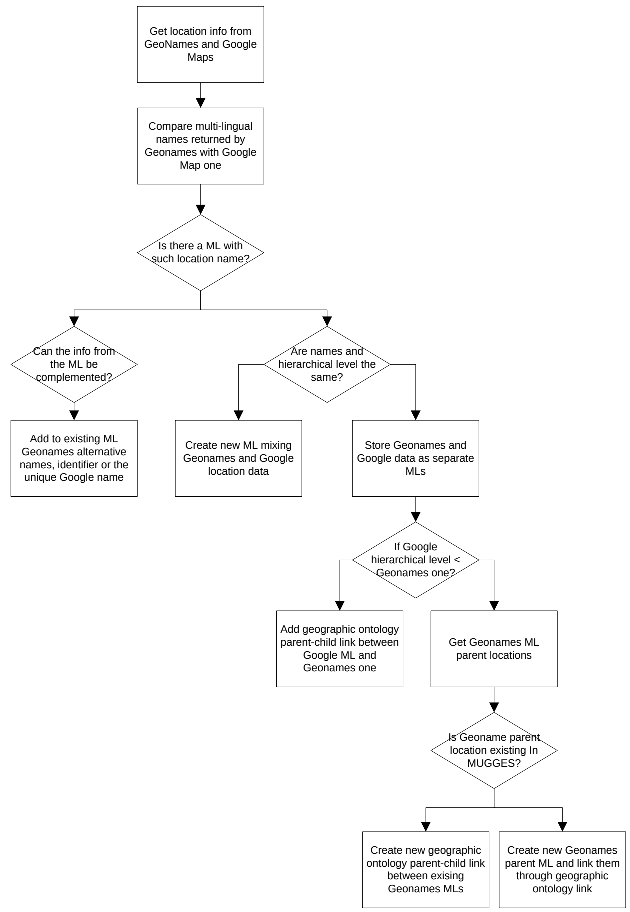

Figure 4. MUGGES Location merging algorithm

A. *Assessment of Trial Results*

Based on the obtained data, we analyzed MUGGES acceptance, its spatial-temporal usage and workflow. The questionnaire issued at the end of the trial revealed that users would use MUGGES once a day, being factors such as weather conditions (trial was conducted on rainy winter days) or the unpolished implementation of the MUGGES client, the major reasons to refuse it usage. In order to analyse the spatial distribution of MUGGES activities we considered 3 tasks.

- **Mugglet creation.** During the trial a total of 387 Mugglets were created (published) and most of them (84 %) were basic MUGGES Note Mugglets. The proportions of mash-up mugglets from all created ones were: MUGGES Journal 8%, MUGGES Trail 8%, and MUGGES Race 3%. The rationale for the small proportion of mugglet mash-ups is based on the fact that they act as special purpose containers of Note mugglets. Most mugglets were created while walking at the university campus or in the direct surrounding area. Figure 5 represents that mugglet concentrations (visualized through the blue circle radius) exist in the campus area and in the centre of Bilbao. These locations represent places with an important meaning for them (e.g. new University library) or places which host day events (e.g. temporary exhibition). Test users reported that the most valuable benefit of MUGGES lies on the possibility to create mugglets right at the point of interest, i.e. without requiring to go back home to a desktop computer. Because of bad weather conditions during the trial (heavy rains) and the lengthy mugglet creation process (see again Figure 2), users normally followed a two-phase workflow taking first a picture of that point of interest and then describing it in a more convenient location e.g. at a restaurant (see red circles in Figure 5). A similar behaviour for the creation of mashup mugglets (e.g. MUGGES Trail or MUGGES Journal) which represent a grouping of MUGGES Notes was also registered. In general, users found that mash-up creation is very powerful and encouraged us to extend the concept by allowing the re-usage of notes from other users. To speed up the mugglet creation process, users suggested pre-creating mugglets for common places, making a better reuse of user and environment information or use voice recordings for commenting. Another important demanded feature was to insert hyperlinks in order to achieve a better connection between the physical and the digital world.

- **Mugglet provision.** During the trial, every user was asked to keep their device permanently online which turned out to be quite challenging since batteries lasted only for half a day. Users later reported us that they would choose to keep their mugglets online for several hours or days but this would depend on the energy consumption or positive feedback of other users. Trial users reported that their devices became slower over time. Analyzing this phenomenon we discovered a strong correlation between the provided mugglets and the execution speed. When reaching to an upper limit of around 30 mugglets, the phone's execution speed resulted unbearable. Since many users created mugglets intended for smaller groups, they requested the chance to address specific friend groups from the mobile interface. Some mugglets were consumed by larger audiences (up to 14 people), i.e. those mugglets were deemed public since most of the population (17) consumed them at some time.

The Peer-to-peer approach adopted in MUGGES architecture supposed several challenges. No more than 5 MUGGES consumers could access the same mugglet simultaneously. This is due to the asymmetric upload- and download link which is counterproductive for the peer-to-peer concept of MUGGES. Besides, when users switched off their phone, the provided content disappeared from consumers, something identified as a major drawback of the solution.

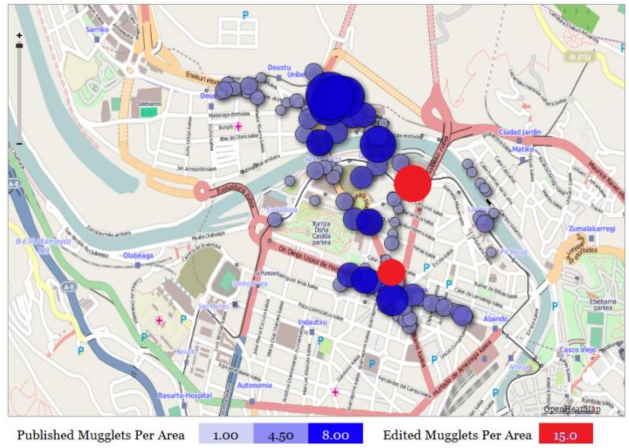

Figure 5. Spatial distribution of Mugglet creation and editing locations

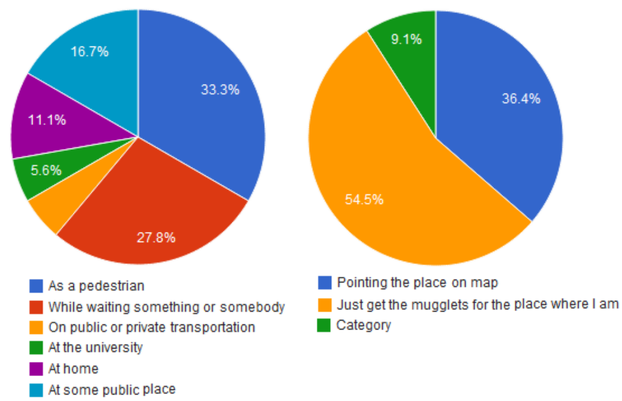

Figure 6. a) Primary consumption scenario and b) preferred search methods.

- **Discovery and consumption of Mugglets.** Mugglet consumptions took place mainly during the second half of the day (between 11:00 to 23:00) in the following circumstances, sorted in decreasing order of their importance (see Figure 6a): 1) while walking, 2) while waiting for somebody, 3) at some public place, 4) at home, 5) commuting and 6) working. Searching for mugglets was easy during early trial phases but decreased later when more mugglets had been created. The keyword search allowed the user to query for the terms used to describe mugglets. Mugglet search under symbolic location specifications was also possible and widely used. The latter was of great help in the early phase of the trial when map based search was not fully implemented. Users suggested us to add the capability of introducing free text search as it may lead to an even more precise mugglet identification. In the later phase of the trial, we activated functions which exploited the hierarchical character of location ontologies to adjust the number of results automatically to the availability of result discoveries. People told us that this feature significantly improved the relevance of displayed results. Comparing keyword- and location based search, users indicated that location based search was the most important one but still not efficient enough. They suggested complementing the location-based search with keyword search which allows querying specific MUGGES domains e.g. specific sport or food places. Also they found that the display of map-based results may indicate specific usage hotspots. With the increasing amounts of available mugglet, colour grading to clearly distinguish between old and recent mugglets was proposed. In total over 950 consumption events (accessing a mugglet from a consumer peer) were logged in the trial. The main activity was concentrated on the campus of the University of Deusto and its surroundings area but most users also examined mugglets from their home locations. In the latter case, consumption took place on weekends and times beyond university hours. Mugglets were consumed often in locations that were different to their bound location. Figure 6b shows how only in 54.5% of the cases users actually narrowed down their search results by their current location. This implies that mugglet consumption often occurs at a different location where the mugglet is bound. This is explained by the fact that according to the questionnaires, mugglet consumption occurred mainly in time killing situations e.g. waiting at a bus stop or for someone or at a public place. Finally, users remarked the lack of proactive features in MUGGES that would notify users when some interesting mugglets at the user location were available.

VI. CONCLUSION

This paper has described the MUGGES service provisioning infrastructure that enables location-aware service provision and consumption directly from mobile devices. Besides, it has highlighted the need of combining different location specification mechanisms and merging their supplied data with external geospatial databases. For that, it has contributed with the design and implementation of an intelligent Hybrid and Semantic Location Management System (HS-LMS). Furthermore, the importance for such an HS-LMS to be user mobility status aware has been remarked, so that it supports improved personalised search and filtering of services and thus increasing user satisfaction.

Intelligent handling of location information is carried out by the MUGGES HS-LMS. For that, it introduces the MUGGES Location (ML) concept, an aggregation of physical, symbolic and semantic location aspects. Notably, MLs are interlinked semantically through semantic vocabularies (ontologies), addressing distinct types of location relations, namely, geographically, politically or administrative. This supports the reasoning about location relationships and eventually about relationships among mugglets, which are always tagged by MUGGES Locations.

Finally, we have undertaken a user evaluation of the system by means of a trial, which has brought forward some usability issues, associated to the MUGGES client-side particularly, performance issues due to the strong resource demands of prosuming devices, and illustrated the spatial-temporal distribution of mugglet provision and consumptions.

The work done in MUGGES paves the way for future adoption of other GNSS-based location technologies such as Galileo. After our trial evaluation, it can be concluded that there is significant user interest on direct location-aware service provisioning from mobile devices. However, future work should consider performing further enhancements to our location mapping and reasoning mechanisms, aided by intuitive web and mobile interfaces that would foster user intervention in the correction and mapping of location data. Although the current state of mobile technology has allowed us to successfully create, deploy and trial the MUGGES architecture, several performance problems due to both the mobile device platform and the public 3G network communication limitations, have been encountered. Future work should consider a reimplementation of the MUGGES infrastructure on some of the emerging and increasable consolidating mobile platforms such as Android or iOS. Lastly, usability on mobile applications is paramount to increase user acceptance. Therefore, a better design of our current mobile front-end should solve some of the deficiencies identified in the user trial, as reported in the previous section.

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REFERENCES

[1] E. Kaasinen, "User needs for location-aware mobile services," Personal Ubiquitous Comput. vol. 7, 2003, pp. 70–79.

[2] M. Fisher. European Mobile Mapping Trends. [Online], 2008, http://tinyurl.com/6b3fnf8

[3] MUGGES. Mobile User Generated Geo Services. [Online], 2011, http://www.mugges-fp7.org

[4] Foursquare. Foursquare. [Online], 2011. http://foursquare.com/

[5] YELP – Real people, real reviews. YELP – Real people, real reviews. [Online], 2011. http://www.yelp.com

[6] Pelago Inc. Whrrl - Are You In? [Online], 2011. http://whrrl.com

[7] Plazes AG. Plazes - Right Plaze, Right Time. [Online], 2011. http://plazes.com

[8] Google Inc. Google Latitude. [Online], 2011. http://www.google.com/intl/en_us/latitude/intro.html

[9] Loopt. Loopt - Discover the world around you. [Online], 2011. http://www.loopt.com

[10] Google Inc. Google Maps API. [Online], 2011. http://code.google.com/intl/en-US/apis/maps/

[11] S. Tarkoma et al., "Spice: A service platform for future mobile ims services," in *World of Wireless, Mobile and Multimedia Networks, 2007. WoWMoM 2007. IEEE International Symposium on a*, Los Alamitos, CA, USA, 2007, pp. 1-8.

[12] Project m:Ciudad FP7. Project m:Ciudad FP7. [Online], 2011. http://www.mciudad-fp7.org/

[13] C. Becker and F. Durr, "On location models for ubiquitous computing," *Personal and Ubiquitous Computing*, vol. 9, 2004, pp. 20-31.

[14] C. Jiang and P. Steenkiste, "A hybrid location model with a computable location identifier for ubiquitous computing," *UbiComp 2002: Ubiquitous Computing*, pp. 307-313, 2002.

[15] Y. Li, F Pu, and Q. Cao, "Semantic Location-Aware Model for Ubiquitous Computing," in *Information Science and Engineering, 2008. ISISE'08. International Symposium on*, 2008, pp. 467-470.

[16] JSR 179 Location API for J2ME™version 1.0.1, Specification. http://www.developer.nokia.com/info/sw.nokia.com/id/56a9a94a-ab11-4f6a-84c4-4ee7ada2a7e8.html. [Online], 2006

[17] NGA, World Geodetic System. [Online]. http://earth-info.nga.mil/GandG/wgs84, 1984

Figure 7. MUGGES Applications interfaces – a) MUGGES Note, b) MUGGES Note photo view c) MUGGES Journal, d) MUGGES Trail and e) MUGGES Race