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Exploiting Context in Location-Based Information Systems

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***Abstract*—The area of mobile location-based information systems enumerates many systems that enable their users to digitally annotate physical locations, providing in this way information to others about these locations, communicating with other people in the proximity and publicly expressing their opinions and thoughts. However, no attempts have been made to facilitate the user in describing important situations through annotations and further on, to analyze the textual data provided in the annotations, in order to extract useful information and exploit this information for the benefit of others. We argue that these annotations could be proved critical, as long as the system exploits their content and the context. In this work we propose a mobile location-based annotation system with enhanced context-aware functionality, which enables users to textually annotate public spaces, mainly streets and squares, in order to inform users and authorities about hazardous circumstances, public issues and other important information.**

Keywords-location-based systems; annotation content; context-awareness; ontology-based methods; keyword matching; mobile applications; ubiquitous systems

I. INTRODUCTION

The aim of location-based annotation systems is to provide users with the ability to produce and access information that is related to a location. Through these systems, users are able to electronically annotate physical locations, their surroundings, as well as objects in their proximity. Many such systems have already been proposed [2,3,7,8,9]. The digital annotations in these systems may be used as pieces of information about the location, as recommendations about which locations are best offered for certain activities such as eating, drinking, studying, dancing etc., and as reminders to others about things they have to do, places they need to be and people they have to meet. Despite the fact that these systems differ from each other in many technical aspects, they all provide a basic annotation authoring and accessing, but not annotation filtering.

In general, users seem to agree that digitally annotating locations is useful in two cases: first to provide information for that particular place, so that others may benefit [7] and second to leave a practical reminder or note to other people [8] (such as "*I'm currently way from the office. I will return at 15:00*"), the first occasion being the most popular. Indeed, people welcome other people's suggestions about where is best to eat and drink in an unknown environment such as a big city, and at the same time they themselves are willing to provide information about places they've been.

We introduce a third case in which the process of digitally annotating locations can be proved useful: to provide information about hazardous situations and public issues in open public spaces, like streets and squares. People daily observe many events, facts and situations that provoke them to react in some way, but strangely, very few of them react at all. These situations are not critical enough to explicitly involve authorities, like a road accident, a fire or a fight among sports fans, but rather more insignificant situations that may bear potential danger, public disorder or personal frustration. An example would be a road left in a bad condition or a bus being repeatedly late. Despite their lower significance and their not life threatening nature, these issues must be addressed to the appropriate authorities, as well as become known to the public. None of the aforementioned systems may adequately be used for promoting such information. Users are currently only able to annotate in regards to express their opinion about a place and not to promote potentially hazardous situations. Their annotations are only accessible by other users and not authorities. In addition, these systems do not attempt to understand the content of users' annotations, something that could lead to important information about the location, the user and a fact connecting the location and the user.

In this work we propose a mobile location-based annotation system that will enable its users to textually annotate open public spaces, such as streets and squares, in order to inform authorities and other users about: 1. potential hazards and 2. public issues and thoughts. Users will have the option to specify the importance of their message. Their annotations will be lexically analyzed, in order to extract useful information. Next, based on the analysis results, the importance of the annotation and its popularity among users, information will be classified, prioritized and forwarded to appropriate recipients: other users and authorities. Users will be benefited by being informed about hazardous situations and issues that may concern them, while authorities will be informed real time about public places that may bear danger, in order to take appropriate action. In this paper we present the overall system architecture, concentrating on the Context-Awareness Module of the system.

The paper is organized as follows: after discussing related work in section 2, section 3 describes the proposed system regarding the overall system architecture, focusing on

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the context, the reasoning upon the context and the novelty in functionality provided to end users. Section 4 describes a usage scenario and discusses what is novel about the proposed work. The scenario demonstrates how users could use the system to inform other users and authorities about hazardous and important issues, as well as be informed about issues of their concern. We explain how the system reasons based on the context and how users are becoming aware of information that is most relevant to their needs. We finalize the paper by summarizing and discussing future work.

II. RELATED WORK

Many location-based annotation systems have been proposed in the bibliography. GeoNotes system [9] connects information pieces to positions in outdoor or indoor space. The user enters data to the system by associating them with a specific location. One of the novelties of this system is that it uses a "place label" to indicate where exactly the annotation is placed. The Grafiti context-aware system [2] allows users to define what's relevant and interesting about a location by posting electronic notes. Users may provide information like where is best to eat, or what movies are interesting. The system reasons with only two context entities: location and identity. E-graffiti [3] is a context-aware application that detects users' location and displays text notes to them based on their location. In [8], a location-aware messaging system is presented that lets users read and post notes linked to a particular location. The system leans towards the aspect of leaving notes to places as personal reminders attached to those places. City Flocks [7] is a mobile system that enables visitors and new residents in a city to be informed about their new environment by local residents' comments on any place or physical object in the city.

In the area of location-based notification systems (LBNS), many works offer awareness through notifications in various domains like police patrolling, firefighting and tourism. In [5], a mobile service is presented that notifies police officers about warrants, agreements and police focal points in their vicinity. The results of a field evaluation showed that police officers were better informed about their environment, however, officers complained that the system offered too many, often irrelevant notifications. The need to filter the notifications was apparent and was proposed as future work.

User studies on some of the above annotation systems have shown that users had failed to use these systems in the way their creators envisioned they would do. [2], [3] and [8] mention some of the problems that such systems encounter, such as their inability in motivating the user to use the system properly. In [2], users saw the Grafiti system as a means to exchange messages between them, like e-mail or instant messenger. Many commented that they had *"nothing useful to say"* or had *"no reason to post a note"*. Moreover, they didn't check for notes on the Graffiti system, because *"others weren't using it"* and because *"messages were of little value"*. In [3], users would use E-graffiti to chat with others nearby, advertise sites, ask questions or request help. The authors stated that motivating users to contribute in the system was a real challenge: *"the fewer people using the system, the fewer notes people will contribute and the less value others will get out of the system by reading those notes"*. A user study in [8] showed that the majority of users thought the system was useful for leaving notes to places as reminders, or as notes to others to denote absent (e.g. "I will return to the office at 11pm"). Users also liked being able to check a person's availability (is he/she at the office?) from a remote location since it saves them the time and effort to get to the office. In [7], users have successfully used the City Flocks system to be informed by others' comments about particular places that are best for certain activities, such as having lunch. The outcomes of the user tests have shown that user comments were perceived as an extremely valuable source of information when navigating new urban environments.

Users are motivated to digitally annotate a location only to provide information for that particular location in the form of a suggestion or commend or to leave a reminder or note to others. Systems that only provide users with the means to annotate without giving them a motive are not perceived as useful; therefore, users do not use them. In this paper, we propose a system that enables users to promote important information relevant to hazardous situations and public issues. The need for such a system is imperative, since it contributes to solving real every day problems. This work differs from the related work as to the enhanced functionality provided to users when annotating a location and the context-aware method proposed for prioritizing the annotations based on a scoring procedure. More about the proposed system and its functionality are discussed in section 3.

III. THE PROPOSED SYSTEM

A. System Architecture Overview

The overall system architecture is presented in Fig. 1. Users will be able to annotate a location by using their mobile devices. The device forwards annotation data to a server, along with the location data provided by the GPS receiver. These data are made available to the Context-Awareness Module, in order to store relevant information to the ontology and reason upon this information via the Context Reasoning Mechanism. The aim is to forward appropriate information to two groups: authorities and users.

In this paper we focus on the Context-Awareness Module, rather than providing a detailed definition of the system architecture. Important aspects towards our approach are the annotation content, the context definition and the context reasoning. We present the designed ontology and the reasoning method currently being implemented. The novel functionality resulting from the above is also discussed.

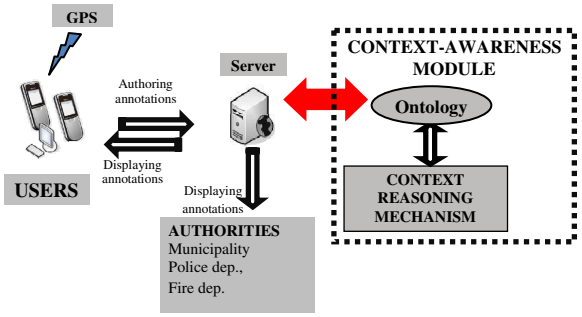

Figure 1. The Overall Architecture of the System

B. *Annotation Content*

In previous works the location-based information systems described are able to provide much information about the location, but little regarding the context in which this information was created. In [4] the authors mention that *"research in ubiquitous computing mainly has focused on place as 'location', leaving context aware computing a long way from systems that compare with the context awareness we demonstrate as humans in our everyday lives"*. We will attempt to explore the information beyond the location, and find out more about the context in which annotations are being created.

The most important aspect of location-based annotation systems is that they provide users with the freedom to arbitrary express what they feel through annotations. However, none of the available systems attempts to understand what the user wants to say, and by that, to take his attempt to inform a step forward. The content of users' annotations is unimportant information for the systems themselves; they handle each annotation in the same way, regardless the annotation content. Moreover, they utilize only a few trivial contextual factors, such as location, time and user identity (some of them may use more information e.g. to suggest annotations that friends authored or liked). We will attempt to upgrade the functionality proposed by these systems. Our vision is a system that understands what the user is trying to say and handles his messages in a more intelligent way than just pushing it to every mobile phone in the proximity, to ones friends or publish it on a web page. Particularly, the research goals of this work include the following topics: 1. the context of mobile location-based annotation systems for use in public city spaces, 2. how a system may facilitate the user in the process of annotation, so that the annotation itself has a meaning and 3. how a system may use the context (including the user input) to reason about the annotations, classify them and prioritize them. Based on 1, 2 and 3 we propose a system for promoting information to two groups: other users and authorities.

C. *The Context*

According to Day, Abowd and Salber [1], *"context is any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application including the user and applications themselves"*. The context in which an annotation is being created includes entities such as the location, the content of the annotation, the user that creates it, his profile information (interests, mood, personality etc.), the time of creation, the weather conditions (for outdoor locations) and more. In fact, during the actual process of annotating a location, countless contextual factors can play a significant role, but only few of them are traceable and computable. We define the most important and at the same time computable contextual entities in the following paragraph.

Being aware of the context is in general a challenging task and, in particular, very important in ubiquitous computing. There are many approaches for modeling the context in ubiquitous systems [10]: Key-Value Models, Markup Scheme Models, Graphical Models, Object Oriented Models, Logic Based Models and Ontology Based Models. For the purposes of this work we chose the ontology model, due to its effectiveness in describing concepts and facts of our every day life, as well as the associations among them.

In Fig. 2, we present the designed ontology that depicts the context in the proposed mobile location-based annotation system. We define the following contextual entities: the *keywords* entity, the *annotation*, the *category* of the annotation, the *importance* of the annotation and the *support* of the annotation.

The keywords entity includes a set of words that semantically describe other entities, such as an annotation, a user or an authority.

The annotation is a piece of textual information that may contain keywords. Each annotation is semantically described by: 1. the keywords fount in its text and 2. by any additional keywords the user might have specified to describe that annotation.

The category of an annotation is denoted by the author to explicitly specify if the annotation will be forwarded to a certain authority, to the public or to both.

The importance of an annotation declares the degree of importance that the author has given to his annotation.

The support of an annotation is the amount of supports the annotation has received by other users: if many people supported an annotation, then that annotation is popular, hence important.

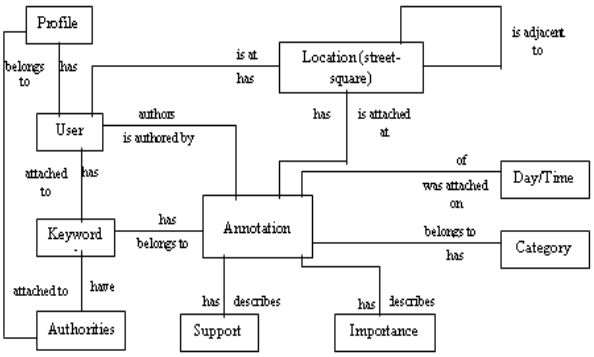

Figure 2. The context ontology

D. Context Reasoning Mechanism

The reasoning mechanism aims at specifying the *criticality value* of each annotation. Based on the criticality value, the annotations will be prioritized to be projected to the appropriate recipients ranked. A recipient may be a user or an authority. The criticality value is affected by three factors (also shown in Fig. 2): the *importance*, the *support* and the *keywords*. Regarding the keywords factor, each recipient, either a user or an authority, has a certain profile which includes certain keywords. These keywords characterize the particular recipient. For example, a keyword for a user can be "bicyclist" if that user is a bicyclist, while a keyword for a municipality can be "public road" because issues that have to do with public roads concern it. The scoring of the keywords factor is based on the amount of common keywords between the annotation and the recipient.

The scoring procedure that determines the criticality value for each annotation is designed based on the Relevance Function (1) [6]. The Relevance Function is the weighted sum of the contextual factors and relevance weights that are used to compute the criticality value of each annotation.

$$R(x) = (W_1*imp+W_2*sup+W_3*f(key)) / (\sum(W_i)*3) \quad (1)$$

R(x) corresponds to the criticality value for the annotation x. W_i denotes the corresponding weight for the factor i, while *imp*, *sup* and f(*key*) are the scoring results of the importance, the support and the keywords factors for an annotation. The value of each weight W_i is to be explicitly defined by the user, as the means to denote personal preference to any one (or more than one) of the 3 factors. The values of *imp* and *sup* variables are also to be determined by the user, while the scoring result f(*key*) is to be calculated by the system based on the annotation and the user profile information, as described earlier. The determination of the best range of values to be used for the weights, the importance and the support is in our current research plans.

Based on the above, for any given user and authority, the system will be able to compute a criticality value for each annotation, by using (1). This value can be regarded as the scoring of the annotation. Annotations with high score are more relevant to the recipient than lower scoring annotations. Annotations will be presented ranked based on this score.

E. System Functionality: What is Innovative?

The innovation of the proposed system regarding the functionality provided to users is discussed in this subsection. By using this system, users will be able to:

1) Specify the importance of the annotation. The higher the importance of the annotation, the more attention the system will give to that annotation.

2) Inform the authorities. The user can specify which governmental authorities and services should receive the annotation. Some potential recipients are: the municipality, the municipal police, the police, the medical department and the fire department. The user can choose among the aforementioned, and based on his choices and on the criticality value of the annotation, the annotation will be presented appropriately to the corresponding recipients.

3) Explicitly alert people belonging to certain social groups, such as bicyclists, motorcyclists, taxi drivers etc.

4) Inform all people being currently located (or will be located) near by the annotated street or square.

5) Alert people that plan to pass by the annotated street or square. Users can denote their route in the city through an electronic map and the system can alert them about potential hazards and dangerous situations related to their route.

6) Pinpoint a location, so that the user may later annotate it. When a user drives by a location that wants to annotate, he is provided with the option to pinpoint the particular street, by pressing a single button on his mobile device. The device would record the location. Similarly, a user could pinpoint many locations he would like to annotate. Later on, when he is idle, the system will prompt him with all pinpointed locations so that he may annotate them.

None of the available location-based information systems facilitates the informing of authorities with people's annotations. They do not support the users in denoting the importance of an annotation, providing related keywords or supporting annotations of others, so that to reason upon this information and rank the annotations in respect to their criticality, prior to presenting them. The proposed system in this work includes the above functionality. Next, we present a scenario that describes the annotation authoring process and depicts how users and authorities are informed.

IV. SCENARIO

A. Outline

Jerry is a family man who lives in the city with his family. Every day he drives his children to school on his way to work. He passes through Larnacos street, a main street in which road works were recently conducted and which was left in a bad condition, full of dangerous holes and humps that cause a feeling of anxiety and discomfort to all drivers and pedestrians. The people responsible (the head of the road works, the municipality, the police and the state) don't do anything to improve the condition of the road. Every time he drives on that particular street, he feels the need to complain to authorities about its bad condition, but he doesn't have the means to do so at that particular moment. Later at the office his routine absorbs him and he forgets about the issue. He feels disappointed because as a tax paying citizen he expects the state to watch out for him instead of putting him in danger. He would also like to inform all his friends and relatives who live in the same city, so that they would be careful when driving by. In addition, as a bicyclist himself, he would like to alert the bicycle community, as well as the motorcycle community about the situation, since these groups are more underlain in danger than car drivers. Having in mind the available technological means nowadays, his options include mobile phone text messages (sms), emails, chat client applications (like MSN) and social network

support tools like forums, blogs, facebook etc. (provided he is a member of any). He also thinks of ways to inform all people that plan to drive, walk or ride on that street about its bad condition, but he can't think of any. Maybe it would be good to notify television stations, radio stations and newspapers as well. A Saturday morning, the only day besides Sunday of no work, Jerry decides to take some action. He makes a phone call to the municipality to alert them about the situation, only to find out that it is a day off for them as well. He would have to call on a working day and during working hours, something not comfortable with, since he would be busy with his own work at those hours.

B. Discussing the Scenario by Using the Available Location-Based Information Systems

By using one of the available location-based information systems, Jerry would have been able to annotate the current location, Larnacos street, providing information to others about the important situation. However, he would not be able to denote the importance of his annotation and more importantly, he would not have the means to inform the authorities about the issue, neither particular social groups. In addition, systems that would push Jerry's message to mobile devices of people passing by the particular street (in-situ accessing) would be unhelpful for our scenario, since a notification to avoid a road is meaningless if it reaches users at the time they are already passing by it. Remote access would be more beneficial for this scenario, since it would inform users not to choose the particular road when in search for the optimal route to their destination.

In addition, to post the annotation in-situ, Jerry would have to park his car, write the annotation and digitally attach it to Larnacos street. To post the annotation remotely, he would have to remember to annotate it from work or home, remembering at the same time the exact location. By using the process of pinpointing a location, Jerry not only has the chance to later annotate the street, but he cannot forget it as well, since the system will constantly remind him to do it.

C. Discussing the Scenario by Using the Proposed System

By using our proposed mobile location-based annotation system, Jerry would have the following abilities, which are absent from the available location information systems:

1) Specify the importance of the annotation:

After writing the content of the annotation, Jerry can specify its importance. He chooses "high importance", because it is an issue that involves hazards for people. Now, let's suppose that Jerry's annotation content is: *"There is a great danger in this street*[1] *because the road is in a very bad condition, full of holes and bumps. Drivers, pedestrians, bicyclers and motorcyclists should be very cautious. Please be very careful at night, because the lighting is also poor"*. The system will be able to lexically analyze the content of the annotation, and extract a set of meaningful keywords. For example, in this scenario, keywords could be: danger, bad, holes, bumps, drivers, pedestrians, bicyclers, motorcyclists, careful. There are 5 keywords that denote danger (underlined), which will affect the reasoning mechanism in deciding the criticality value of the annotation. Regarding other user's support, currently no such supports exist for Jerry's annotation. Had there exist any, the system would take them into account in calculating the criticality value of the annotation.

2) Inform the authorities

After specifying the importance of his annotation, Jerry specifies which authorities should receive the annotation. He chooses the municipality because they are responsible for the condition of the roads and the police to notify them about potential accidents in Larnacos street. The two authorities will receive his annotation through a group of ranked annotations. Jerry's annotation has much potential to be high in the rankings, due to its high criticality value.

3) Alert people that belong to particular social groups

By using the words "drivers", "pedestrians", "bicyclers", and "motorcyclists" in his annotation, Jerry indicates to the system to alert people belonging to these social groups. The system searches all user profiles and notifies all users in the driving, bicycling and motorcycling communities. In fact, because Jerry mentioned the pedestrians as well, the annotation should be forwarded to all users, since anyone of them could walk by that street.

4) Alert people located in adjacent streets

Devices in adjacent streets will receive the annotation.

5) Alert people that plan to pass by that particular street

These people would be alerted through an electronic map (his annotation appears on the map at the particular location).

6) Pinpoint Larnakos street while driving to later annotate it

The device would record the location and afterwards prompt Jerry with the pinpointed location so that he annotates it. In this way Jerry not only will not forget to annotate, but he does not need to remember the exact location as well.

D. How Other Users and Authorities are Benefited

Jena, Andreas and John are bicyclists living in the same city as Jerry but in different city areas. Every Thursday night they ride their bicycles through the city and by Larnacos street to go to a pottery class. By using the existing location-based information systems, each one of these users would have to explicitly search all roads and available locations in their city route through an electronic map (if available) for other users' annotations, and read one by one to opine whether a potential danger exists. Since these systems do not distinguish, categorize or prioritize annotations, they do not have the appropriate functionality neither to alert users, nor to accommodate their search.

We suppose Jena, Andreas and John are using our mobile location-based annotation system. We assume that Jena had specified in her user profile that is a bicyclist, but Andreas and John did not. When Jena enters the system before going to her pottery class, the system will automatically alert her with Jerry's annotation, because Jerry explicitly stated that his annotation should reach people belonging to the bicycle

[1] There is no need to specify which street, since the annotation will be attached to the particular location.

social group (paragraph 4.C.3). Jena agrees with his message, so she supports his annotation. In this way she helps in forwarding this information to more people, since the criticality value of the annotation increases through supports and thus the annotation gets higher in the rankings (more noticeable). When Andreas enters the system, he will not automatically receive Jerry's annotation, because, regarding the system, he is not a bicyclist. Andreas then specifies in the system the city route from his house to his pottery class through an electronic map, indicating the streets he will follow (he could store the specific route in the system, since he uses it often). The system then alerts him with Jerry's annotation, since he is going to pass by Larnacos street (paragraph 4.C.5). Let us assume that John forgets to enter the system before his pottery class. He always carries though his mobile device with him. He rides his bicycle on his way to the pottery class. When he arrives at Euripidou street, a road adjacent to Larnacos street, he receives Jerry's annotation and decides to follow another road instead of passing from Larnacos street (paragraph 4.C.4).

Jena, Andreas and John have received Jerry's annotation, each for a different reason. In each one of the above cases, the available annotations could have been more than one. These annotations would have then been classified and prioritized based on their criticality value, and next, they would have been presented to these users ranked. In this way, the most critical annotations are presented first.

None of the available location-based information systems facilitates the informing of authorities with people's annotations. By having the proposed system in use, Jerry's annotation would have reached the municipality and the police in real time (paragraph 4.C.2). The criticality value of Jerry's annotation would have played an important role regarding the authorities as recipients. The municipality and the police would receive his annotation through a group of ranked annotations to which their authors had also specified the same authorities as recipients. Jerry's annotation has much potential to be high in the rankings, due to its high criticality value.

V. DISCUSSION AND FUTURE WORK

Through user studies in the bibliography, users seem to agree that digitally annotating locations is useful to provide information for that particular place to benefit others, and to leave a practical reminder or note to other people. In this paper we introduced the case of providing information about hazardous situations and public issues in public urban places, like streets and squares. We addressed the problem where people daily confront situations not critical enough to explicitly involve authorities, like the police, but rather more insignificant ones that may bear potential danger, public disorder or personal frustration. Dealing with these issues could be proved very important for enhancing the urban every day life. Next, we have proposed a mobile location-based annotation system for promoting important information relevant to hazardous circumstances and public issues in open public spaces. The system will enable users to textually annotate open public spaces, such as streets and squares, in order to inform other users, as well as authorities, about potential hazards, like a bad maintained road, or other public issues. We have described the context of the proposed system through the design of an ontology. We have presented the reasoning mechanism, along with the contextual factors this mechanism uses to infer the criticality value of each annotation. The criticality value is vital for the ranking of annotations during their display to the appropriate recipients. Moreover, we have described the new functionalities the system offers and through a scenario we illustrated how these functionalities give a novelty value to the system.

Future work involves determining the best range of values to be assigned for the weights, the importance and the support being used in (1). Future work also involves issues regarding system implementation, how the annotations will be displayed and how read annotations should be treated.

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