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Performing Relevance Similarity for Privacy in LBS

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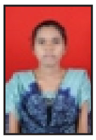

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ABSTRACT:

Location-based applications utilize the positioning capabilities of a mobile device to determine the current location of a user, and customize query results to include neighboring points of interests. However, location knowledge is often perceived as personal information. One of the immediate issues hindering the wide acceptance of location-based applications is the lack of appropriate methodologies that offer fine grain privacy controls to a user without vastly affecting the usability of the service.

While a number of privacy-preserving models and algorithms have taken shape in the past few years, there is an almost universal need to specify one's privacy requirement without understanding its implications on the service quality. In this paper, we propose a usercentric location based service architecture where a user can observe the impact of location inaccuracy on the service accuracy before deciding the geo-coordinates to use in a query.

We construct a local search application based on this architecture and demonstrate how meaningful information can be exchanged between the user and the service provider to allow the inference of contours depicting the change in query results across a geographic area. Results indicate the possibility of large default privacy regions (areas of no change in result set) in such applications.

Index Terms:

Privacy-supportive LBS, location privacy, service quality.

INTRODUCTION:

THE consumer market for location-based services (LBS) is estimated to grow from 2.9 billion dollars in 2010 to 10.4 billion dollars in 2015 [1]. While navigation applications are currently generating the most significant revenues, location-based advertising and local search will be driving the revenues going forward. The legal landscape, unfortunately, is unclear about what happens to a subscriber's location data. The nonexistence of regulatory controls has led to a growing concern about potential privacy violations arising out of the usage of a location based application.While new regulations to plug the loopholes are being sought, the privacy-conscious user currently feels reluctant to adopt one of the most functional business models of the decade. Privacy and usability are two equally important requirements for successful realization of a location-based application. Privacy (location) is loosely defined as a "personally" assessed restriction on when and where someone's position is deemed appropriate for disclosure. To begin with, this is a very dynamic concept. Usability has a two fold meaning— 1) privacy controls should be intuitive yet flexible, and 2) the intended purpose of an application is reasonably maintained.Toward this end, prior research have led to the development of a number of privacy criteria, and algorithms for their optimal achievement. However, there is no known attempt to bring into view the mutual interactions betweenthe accuracy of a location coordinate and the service quality from an application using those coordinates. Therefore, the question of what minimal location accuracy is required for an LBS application to function, remains open. The common man's question is: "how important is my position to get me to the nearest coffee shop?"— which unfortunately remains unanswered in the scientific community.

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Existing System:

Future LBS architectures must make room for a service provider to cooperate with the user in making sound privacy decisions. There is a growing skepticism on how a LBS provider handles (or might handle) location data. If strong market adoption is an agenda item for these businesses, then it becomes their responsibility to present evidence that the sought location accuracy is indeed a characteristic requirement of the application. Further, regulatory enforcements on location data procurement, and subsequent liability in the event of improper handling, can make the collection of unnecessarily precise geo locations an unattractive choice.

From a computational perspective, only the service provider maintains the database of queried objects in real time. Therefore, it is reasonable that differences (or similarities) in the output of a query can be efficiently computed at the server side. A user cannot make informed privacy decisions without this computation. In light of these arguments, a privacy supportive LBS seems both appropriate and important.Note that a simple opt-in LBS is not privacy-supportive, since the implications of not using ones geo location is not available to the user.

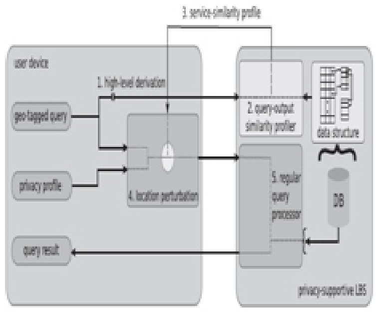

Fig. 1. Communication order for a location-based query in the presence of a privacy-supportive LBS.

Proposed System:

Mobile local search is demonstrating an upward market trend, the gap with the desktop counterpart diminishing in the next three years, and then rising further 2 Given the penetration of web-enabled handheld devices in the consumer market, it has become exceedingly common for a user to instantly look up the information she seeks to find. These search queries are estimated to produce 27.8 billion more queries than desktop-search by the year 2016..

Avast majority of the users performing mobile search seek access to information pertinent in the locality of the query. Multiple LBS applications for example, Where, Around Me, Mee Moi, Skout, and Loopt—have spawned in the past few years to address this market segment. In general, a local search application provides information on local businesses, events, and/or friends, weighted by the location of the query issuer. Location and service accuracy tradeoffs are clearly present in a local search LBS. Aprivacy-supportive variant is, therefore, well suited for this application class. Local search results tend to cycle through periods of plateaus and minor changes as one moves away from a specified location. The plateaus provide avenues for relaxation in the location accuracy without affecting service accuracy, while the minor changes allow one to assess accuracy in a continuous manner.

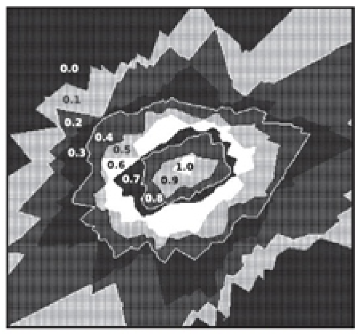

Fig. 2. Hypothetical query result set similarity with the user at the center of the area.

EMPIRICAL EVALUATION:

The empirical evaluation is performed using the SimpleGeo Places data set that contains information on more that20 million places around the world, and distributed under the Creative Commons open license. The US part of the data set has 12,993,248 entries, with data corresponding to multiple business categories and subcategories. Entries are maintained in the GeoJSON format, and includes attributes such as name, latitude/longitude, address, phone numbers, classifiers (category, type, subcategory) and tags. In our study, a place is considered a match for the search keyword if it includes the keyword in any of these attributes, and the city matches the city attribute. The evaluation is performed for the four largest cities in USA—Los Angeles, Houston, Chicago, and New York. One of the factors influencing the top-k results is the number of objects returned by a query, and their distribution around the query point.

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The existence of a large number of objects implies that the top-k results are likely to change for small changes in location. For objects that are low in density, large variations in the location are possible without changing the result set. This behavior can be reasonably assumed irrespective of the density of users in the city.

Therefore, we choose large cities where we can obtain different densities of objects, specially ones with high densities. Objects that are high in density in large cities may not be so in a smaller city. Hence, we believe that a comprehensive evaluation can be performed by considering these large cities.

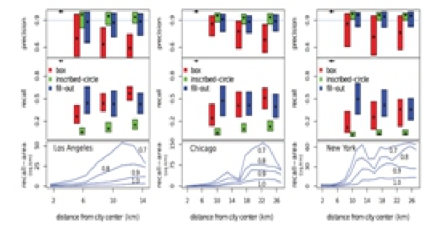

Fig. 5. Precision and recall when searching for "starbucks coffee" in a given city. Each plot shows performance of fill-out for $\delta = 1.0$ (leftmost) and then three sets of rectangles, one each for $\delta = 0.9, 0.8$, and 0.7 (from left to right). Lower edge of a rectangle represents 10th percentile, upper edge represents the median (50th percentile), and the dot represents 25th percentile. Also shown is the area recalled (in km^2) by the fill-out heuristic as a user moves away (distance in km) from the city center. Trend lines are marked with the corresponding δ value.

Precision/Recall Trends:

The precision and recall trends we observe for the case of "starbucks coffee" are repeated for the other medium density experiment (derived using the keyword "police"). For the fill-out heuristic, Fig. 7 shows the mean (across the search keywords) of the 25th percentiles of the precision scores for different object densities.

Full precision for low density objects is almost guaranteed, irrespective of the service accuracy threshold. However, the approach has difficulty maintaining those same values for high-density objects.

High-density objects are often located close to eachother, thereby creating a scenari where moving small distances significantly changes the result set. It also means that finding such objects is not difficult in the real world.

Note that the density designation is not based on what is being queried—a "gas station" could be a high-density object in parts of a city, and low/medium in others.

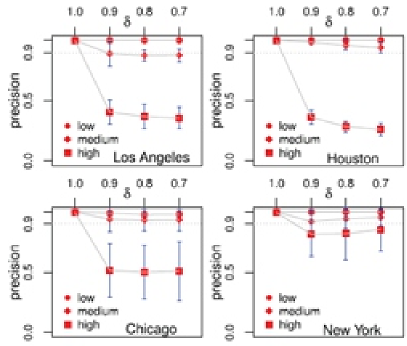

Fig. 7. Precision of fill-out heuristic for different service similarity thresholds ($\delta = 0.7, 0.8, 0.9, 1.0$) and object densities (*low*, *medium*, *high*). Vertical bar shows one-standard-deviation.

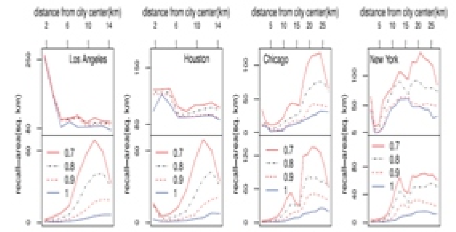

Fig. 8. Area (km^2) recalled by the fill-out heuristic for different service similarity thresholds ($\delta = 0.7, 0.8, 0.9, 1.0$), as user moves away (distance in km) from city center. Top plots are for low-density objects and bottom plots for medium density objects.

Conclusions:

Based on the observations from the empirical study, we make the following conclusions on the efficacy of a privacy supportive local search application. Precise geo locations are necessary for result set accuracy when the queried objects exist as a dense cluster in the search area. It seems unlikely that both location privacy and result exactness can be maintained in this case.

A privacy supportive application would allow the user to aggressively Trade off the service similarity requirement to determine a sufficiently large area for location perturbation. Given the high density of objects, resulting objects can still be expected to be in the near vicinity. When object density is not dense, location accuracy has a minor role to play in retrieving relevant results. A privacy supportive application would help identify the large default-privacy regions resulting in such situations.

SUMMARY:

In this paper, we proposed a novel architecture to help identify privacy and utility tradeoffs in an LBS. The architecture has a user-centric design that delays the sharing of a location coordinate until the user has evaluatedthe impact of its accuracy on the service quality.

Using the prototypical example of a local search application, we showed the form of information that can be exchanged between the user and the provider to enable a privacy supportive LBS. Section 4 of the online supplementary file suggests some future directions of research for this work.

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