Towards QoC-Aware Location-based Services

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Abstract. As location-based services on mobile devices are entering more and more everyday life, we are concerned in this paper with finding ways to master the level of quality of location information in order to take relevant decisions. Location being a typical example of context information, we manipulate it using the COSMOS framework that we develop for the management of context data and their associated quality meta-data or quality of context (QoC). We consider several QoC parameters that are important for location and determine how the QoC can help a location aggregator component to identify the current region where a user is located. The mechanisms we propose support a pragmatic approach in which application designers or deployers survey an area to demarcate regions surrounding locations, and application users are localized into these regions and are presented with the quality of the estimate. We report on the experimentation we performed on the campus of our institute collecting information from Wi-Fi, 3G networks and GPS signals, and show the accuracy we obtain at no additional infrastructure cost.

Key words: Context, quality of context, location, uncertainty.

1 Introduction

Even though context information has long been identified as a corner stone for mobile, ubiquitous or pervasive applications [6,5], only a few systems do pay attention to the Quality of the Context information (QoC). Location is an example of context information that we propose to manipulate using the COSMOS[1] context management framework that we develop. COSMOS allows to take into account the QoC associated with context data and to integrate it in the decision process. We show in this paper how introducing the QoC in the inference process can help a location aggregator component to derive the most accurate symbolic location with respect to the real user position from a set of input location information originated from different sources.

Nowadays, off-the-shelf devices commonly offer GPS reception in addition to Wi-Fi and 3G cellular network communication. This naturally leads to the idea

[1] http://picolibre.int-evry.fr/projects/cosmos.

of an abstract location interface [10] to support deriving locations from different positioning technologies. The ability to take into account multiple position sources also provides the means to remove any frontier from outdoor to indoor positioning, building the location information from the currently available sensed data. The approach we follow is depicted in Figure 1. Let us take the scenario of the preparation of a geo-localized game and of a game session. Game designers survey the area where the game is going to take place. They use a location survey tool installed on their mobile phone that senses the position with a GPS sensor, a Wi-Fi sensor and a GSM sensor. At some positions, they take fingerprints of the sensors and tag the positions with meaningful names so that the positions are marked to be locations, that is distinguished positions. Periodically, the tool collects the fingerprints of position sensors of the same types as the ones used during the location survey. These context data are intersected with the location data of the game to obtain estimated locations, one per position sensor type. In our work, location data are complemented with QoC data and the estimated locations can be aggregated to choose the best QoC-based location, which is itself complemented with region data in order to be graphically displayed on the map of the game application.

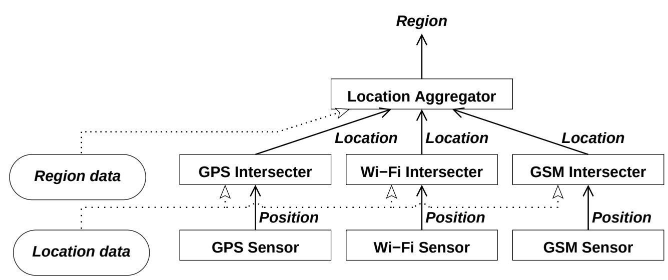

Fig. 1. Location model

The organization of this paper is the following: Section 2 describes the role of QoC in the inference process. We show in Section 3 some evaluation results obtained with a prototype we developed. In Section 4, we discuss related work and Section 5 concludes this paper.

2 Qoc-aware Location

The multiplicity of positioning sources calls for the need to determine the quality of the derived location information.We propose to rely on three QoC criteria which are accuracy, freshness and trustworthiness; the context management framework we rely on allows to easily extend this set of criteria if necessary. Positional accuracy, or accuracy, represents the degree to which the reported location matches the true location in the real world. It can be determined statistically from a set of experimentations comparing the estimated location and the real one. As location is a very dynamic notion, an evaluation of its freshness (or up-to-dateness) appears essential. We compute the freshness as a function of the age of a position measure, represented by the time elapsed since the measure was taken, and of its lifetime [7]: $freshness = 1 - (t_c - t_m)/l_t$ where t_c is the current time, t_m is the measurement time and l_t corresponds to the lifetime. Trustworthiness has been considered in several works [2,12] as a QoC criterion allowing to rate the context sources indicating how much trust can be put in the input data. With regard to positioning, we define the trustworthiness as the probability that the derived location information matches the real location of the user. Its computation depends on the relevancy of the available information, linked to the source of the information, and also on the technology used. We compute the trustworthiness of a Wi-Fi-based location as $T_{WiFi} = O_r * S_s$ where O_r is the overlapping ratio of the received signals w.r. to the survey phase and S_s is the total difference of the signal strengths. For GSM signals, our experiments show a high instability in the strengths of the received signals. We therefore derive the trustworthiness of a GSM-based location as: $T_{GSM} = O_r$. The trustworthiness of a GPS information is defined as follows: $T_{GPS} = (D_r - d_{rp})/D_{max}$ where D_r is the diameter of a predefined region, as registered during the survey phase, d_{rp} is the distance between a given predefined region and the current position, and D_{max} is the maximal diameter that we consider for a region.

Based on the location information and its quality meta-data provided by the various intersecters, a Location Aggregator component performs a fusion process driven by the knowledge of the quality of the location information. Locations are sorted according to their trustworthiness, freshness and accuracy, in this order. The location that is ranked first is chosen. When several intersecters provide the same location as a result, the QoC criteria of the aggregated region are computed as the maximum values of the input QoC.

3 Evaluation Results

We have conducted series of experiments on the campus of our institute using a prototype we developed based on the COSMOS process-oriented context manager [4] which supports QoC processing [1]. This experimentation implies two phases. The first phase is the location survey during which we register the Wi-Fi, GSM and GPS signatures of several locations that we tag with a symbolic name. The second phase consists in testing the behavior of the location detection application by going to a registered location and obtaining the location derived by the system.

For each kind of positioning technology, we have performed some specific measures to determine the most appropriate calibration of the location detection application. For the Wi-Fi Intersecter, as shown on Figure 2, we have determined that an overlapping ratio of 50% reached the best accuracy. We see on Figure 3 that a *SignalStrength* of $-90dBm$ gave the best accuracy. It represents the threshold for the strength of the received signal below which a signal is ignored. With this parameter setting, we obtained an accuracy of 0.72 meaning

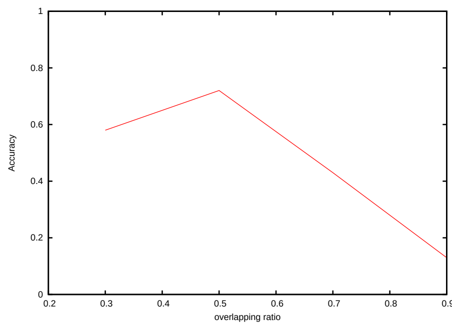

Fig.2. Wi-Fi Overlapping Ratio

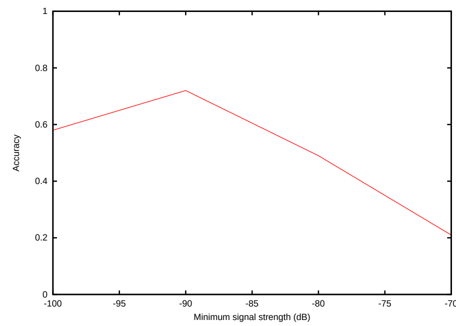

Fig.3. Wi-Fi Signal Strength

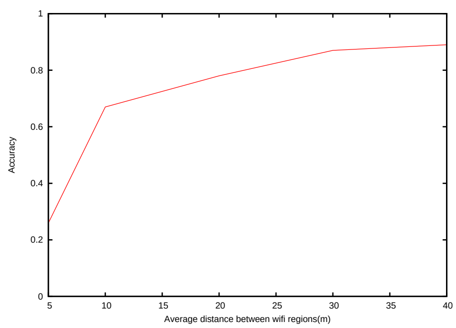

Fig.4. Wi-Fi Avg distance btw Regions

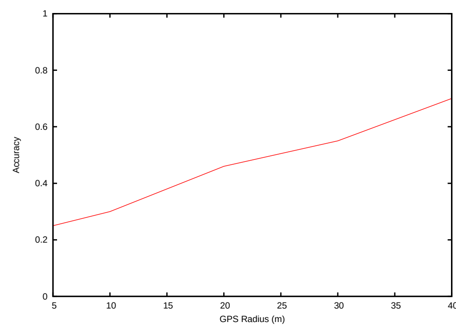

Fig.5. GPS diameter

that the location detection application indicates the correct location in 72 % of the experiments.

In Figure 4, we analyze the impact of the actual distance between the tested locations. As can be expected, the sensed information must be different enough for the system to be able to distinguish between regions. When regions are separated by more $20m$, $30m$ or $40m$ we obtained the correct location in 78% of the experiments, 87% or 89% respectively.

For the GPS Intersecter, a default value of $10m$ has been chosen for the maximum radius of a GPS region as shown on Figure 5 reaching an accuracy of 30%. The best accuracy of 70% was obtained with a radius of $40m$, but this does not allow to sufficiently differentiate the different places at the scale of the campus.

4 Related Work

We review in this section some related work on positioning middleware that consider the quality dimension of location and also consider more general approaches for dealing with the uncertainty of context information.

Middlewhere [11] relies on three metrics for determining the quality of location information: resolution, confidence and freshness. It also proposes an uncertainty model based on a predicate representation of contexts. However, the resulting quality of location information is not exposed to the applications and the models cannot easily be extended by application developers. [8] makes use of the accuracy as given by the context sources and expressed by a distance and the freshness of the measure. However, this work does not consider additional quality aspects such as trustworthiness as we propose. Nexus [9] considers three quality aspects through degradation, consistency and trust. This model is very powerful but requires applications to specify probabilities in order to perform position queries. We propose a more user-friendly solution where the framework informs the user of the obtained context quality rather than requiring the user to restrict the research domain. The LOC8 framework [13] is a recent effort to provide application developers with easy access to location information. It defines a quality matrix consisting of granularity, frequency, coverage and a list of accuracy and precision pairs. LOC8 also relies on a sensor fusion method, with a default implementation based on fuzzy logic integrating the confidence on location data. While our work results from a similar effort to manipulate different sensor data and to expose the knowledge of its quality, we promote a fusion process that considers a larger set of quality criteria, and not only confidence.

Exploiting meta-data expressing the quality of context information can help to deal with its inherent uncertainty and to resolve the potential inconsistencies that can result from it. For instance, the fusion process we propose for location aggregation can benefit to the context-correlation model of [3]. [14] considers uncertainty regions around the position of mobile objects. Introducing the freshness quality criterion we propose in the proximity evaluation algorithms of [14] would help to filter out old context information.

5 Conclusion

This paper presents our approach for building QoC-aware location-based services. As it is central to the development of a large number of mobile distributed applications, we consider that location information requires specific care to deal with its inherent uncertainty and that applications need to have the knowledge of this uncertainty level. We identify accuracy, freshness and trustworthiness, as being the quality criteria that are particularly relevant for location information, but this list can be extended if required as additional QoC parameters are provided by our COSMOS context management framework. We have prototyped and evaluated a location detection application based on COSMOS showing that we reach a satisfying accuracy during experimentation on our campus. The location detection application provided the correct location in 72% of the experiments. More experiments are planned in making the prototype applications available in a social network on the campus so that students can register their own measures and comment on the obtained results.

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