POSTER
An Embedded Fusion System for Location Management

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Abstract. This paper presents the design and development of a Fusion System that combines data from different communication and location sensors (WiFi, GPS, Cell-Id) to provide consumer location-based services with the best available position estimate. In practice, this location manager is a light module, designed to run in a mobile device and ready to be used by any application requiring seamless indoor/outdoors positioning information. It automatically manages hand-offs among different localization systems. Its logic is based on a decision tree built on an initial set of Quality of Location parameters.

Keywords: localization system, multisensor data fusion, Quality of Location, mobile applications.

1 Introduction

Recently, mobile services increasingly aim at providing the user with personalized features. In particular, location is a parameter that may enable or enhance the functionalities of e.g. guides, navigators or social networks. Thanks to the number of (communication) technologies that are nowadays available in mobile devices, it is feasible to easily retrieve the user's location. When outdoors, GPS, cell-ID and WiFi network identification fingerprints are the most common technologies; these technologies may be used in a cooperative manner to infer location (e.g. [1] [2]). When indoors, it is usually needed to deploy ad-hoc positioning systems to guarantee availability and accuracy. These positioning systems are often built on technologies commonly available in smartphones, like WiFi [3] or Bluetooth [4]. When better accuracy (centimeter range) is needed, the possible choices include e.g. infrared, ultrasounds or ultrawideband, technologies that can be deployed at different costs in terms of resources and complexity. Additionally, beacon-oriented techniques (based on short-range approaches, e.g. bidimensional codes or NFC) may complement any technology deployed in any setting.

These technologies usually work in an independent manner: no internal system to deal with automated positioning technology selection is actually available in mobile application development kits, so each application using location as input parameter has to handle it at its own risk. As location may be used in simultaneous services, it is reasonable to design a fusion system (FS) layer to handle it, to avoid duplicating internal tasks: ideally, this fusion layer will select the best position estimate while

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taking into account the consumer application needs (in terms of accuracy and sampling rate) and the mobile device's resources (in terms of energy and workload). The fusion layer will provide seamless featured location information when the user is moving indoors-outdoors and vice versa, and also when commuting between different indoor positioning systems, handling handoffs and minimizing the time with 'no-location' information.

In order to select the technology to be used in each moment, the fusion layer has to evaluate the Quality of Location coming from the potential options. How to quantify the efficiency and the quality of the estimation has been addressed e.g. in [5][6]: in these works, Quality of Location (QoL) is an aggregated term to analyze the goodness of the estimation, using different features like accuracy, precision, freshness, temporal and spatial resolution. Other approaches try to merge different sources of information when some conflicting situations are detected, as mentioned above in [1] [2](e.g. when not all the sensors are working at the same time) or to develop new algorithms that take advantage of the redundant information [7].

In this paper, we present a preliminary version of the previously mentioned FS, which has been built as a component to be entirely deployed in a smartphone. This component is providing an API, which may be used by any application needing to retrieve seamless location information.

2 Positioning Technologies and Architecture Approach

The FS architecture is designed to run in a mobile device, making use of an external infrastructure only to support indoor localization algorithms that usually rely on local information (e.g. resource maps divided into zones or fingerprints). This local information is stored in a server and is opportunistically downloaded when needed.

For this first implementation of the FS, localization systems based on GPS, Cell-ID and WiFi technology have been integrated, although the fusion system is scalable in number of technologies and algorithms. The system is capable of providing a location estimate whenever any of these technologies are available.

GPS location information is not available when indoors, so in this case, specific localization systems are used:

- *Supervised indoor positioning system*: e.g. in our labs, there is a WiFi network built on four access points (APs), which enables the deployment of received signal strength (RSS) positioning algorithms (fingerprint and propagation channel based ones [8]), each of them providing different accuracy (average 2.5 meters).
- *Legacy unsupervised indoor positioning system*: nowadays, in any office-like environment it is usual to find a good number of different WiFi networks. Thus, we have built an algorithm that takes advantage of the existing infrastructure to match the visible access points with a previously stored fingerprint. The algorithm compares the MAC address of the access points that a device is detecting to a digital map which stores, for a number of selected coordinates, the set of MAC addresses detected in a calibration phase. Obviously, location accuracy depends on the granularity of the calibration phase (how many calibration points have been stored in the database). This algorithm provides a symbolic location (zones), while the previous one provides coordinates.

The decision algorithm logic gives priority to the most accurate technology available in a given moment. When indoor, RSS-based algorithms provides best estimates than MAC-based one. If none of them are available, then the ubiquitous Cell-ID provides its estimate. The accuracy of the estimation is forwarded to the application for it to handle the situation. In this first version of the FS, we have used two features of QoL to choose which source gathers the position estimation from: 1) its accuracy, to put in order each technology in a priority level and 2) the elapsed time since the last measure (availability) for each algorithm, in order to include information about the freshness of the measurement (to decide if an estimation is out of date).

3 Implementation Details

The FS has been developed on an Android smartphone, which includes the necessary sensors for the positioning systems to work. The FS is composed by an activity component, which handles the core algorithm, managing the state of each source of position information (WiFi algorithms, GPS and cell-Id) through four different processes. The core algorithm is also in charge of selecting the most adequate estimate. To that effect, each localization process controls the position estimate that each independent algorithm offers, starting and stopping a service component that represents the sensor access of each technology. In this case, there are three services to gain access to the sensors data.

The four localization processes are qualified depending on their accuracy. The two best ones are GPS when outdoors, which can offer an accuracy from some meters [8] and WiFi RSS fingerprinting when indoors, that can achieve an accuracy of 1,5 meters in best case [9]. If any of these systems are available, the fusion algorithm will not get any other data. Otherwise, WiFi MAC fingerprinting algorithm will be requested to offer its position information. This method can offer a variable accuracy, depending on the separation of the zones where the calibration measurements were taken and, of course, of the stability of the electromagnetic fingerprint (as it is an uncontrolled environment, WiFi networks may appear or disappear without any control). The distance between two zones can cover from few meters up to different floors inside a building. Finally, cell-Id algorithm is the last option, because its accuracy is over several hundreds of meters [10], but available whenever there is cellular coverage.

For demonstration purposes, the activity component representing the FS is composed of several threads. Two of them are continuously running. One of them handles the GUI (Graphical User Interface) - if the FS works as an application -, and the other one launches any algorithm process upon request. It means that, according to what was mentioned in previous paragraph, an algorithm process will start only if it is better qualified. E.g.: if cell-Id is currently giving the position estimation, the processes of the other three algorithms or systems will be active. If, in a given moment, any of them can offer its position estimation, cell-Id process will be stopped, and the new one will keep on running. If the available one is the WiFi MAC algorithm, WiFi RSS algorithm process and GPS process will keep running until they find the position estimation.

Figure 1 summarizes this performance, showing which processes are active and looking for new and recent locations (in rows) depending on the one that is currently offering the estimate (in columns).

		Process giving the location estimate in a given moment				
		GPS	WiFi RSS	WiFi MAC	Cell-Id	None
Active processes, looking for a better estimate	GPS	-	No	Yes	Yes	Yes
	WiFi RSS	No	-	Yes	Yes	Yes
	WiFi MAC	No	No	-	Yes	Yes
	Cell-Id	No	No	No	-	Yes

Fig. 1. Active process depending on the current available location technology

Apart from taking accuracy into consideration, the four processes handle the elapsed time requirement and activate or deactivate a flag, depending on the freshness of the given estimate. For the WiFi RSS algorithm, an extra requirement at signal level has been included: in order to guarantee the correctness of the estimation, this system is only initiated if a sufficient number of access points are visible. In our implementation, we have set this parameter to 3, which is the minimum requested to perform trilateration.

Each process can call each corresponding service, implemented in a new thread. GPS process calls GPS service, cell-Id process calls cell-Id service and both WiFi algorithms call a WiFi service, which makes different tasks depending on the calling process:

- WiFi Service: when this service starts in a new thread, it makes a subscription to the WiFi adapter, demanding an event call when the WiFi sensors scan is finished. Then it stores in a database either the RSS vector coming from the Aps infrastructure (RSS fingerprinting algorithm), or the WiFi MAC vector visible from the smartphone (WiFi MAC fingerprinting algorithm).
- GPS Service: this service makes a subscription to the GPS sensor. This sensor is able to offer the position thanks to the API that Android provides through the SDK.
- Cell-Id Service: in this service, a subscription to cell location changes is enabled. When it occurs, a request to http://opencellid.org is sent in order to get the position of the cell using its identifier.

4 Conclusions

The main purpose of this FS is to provide seamless location information to an application or service, enabling the developer with a single interface to retrieve position data. The adopted approach is light and highly autonomous, capable of minimizing communication needs. It manages handoffs between outdoor-indoor positioning systems, and transitions between supervised and unsupervised indoor positioning systems, aiming at minimizing the commuting time. Together with embedded algorithms for localization, it minimizes the need of performing positioning in infrastructure.

Our current work focuses on enhancing the preliminary model for QoL. The final model should be suitable to optimize resources management in the mobile device (in terms of computation time and energy consumption). Coordinately, we aim at defining an interface for the applications to describe their localization needs. Finally, as the FS is designed to run in the mobile device, it can be part of a system to guarantee privacy control on location information, so how to include some user-centric features to facilitate privacy management is also being considered.

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References

1. Zirari, S., Canalda, P., Spies, F.: WiFi GPS based combined positioning algorithm. In: IEEE Int. Conf. on Wireless Communications, Networking and Information Security, pp. 684–688 (2010)
2. Yeh, S.-C., Hsu, W.-H., Su, M.-Y., Chen, C.-H., Liu, K.-H.: A study on outdoor positioning technology using GPS and WiFi networks. In: International Conference on Networking, Sensing and Control, pp. 597–601 (2009)
3. Kushki, A., Plataniotis, K.N., Venetsanopoulos, A.N.: Kernel-Based Positioning in Wireless Local Area Networks. IEEE Trans. on Mobile Computing 6(6), 689–705 (2007)
4. Cruz, O., Ramos, E., Ramirez, M.: 3D indoor location and navigation system based on Bluetooth. In: Procs. 21st International Conference on Electrical Communications and Computers, pp. 271–277 (2011)
5. Kim, Y., Lee, K.: A Quality Measurement Method of Context Information in Ubiquitous Environments. In: Procs. International Conference on Hybrid Information Technology, vol. 2, pp. 576–581 (2006)
6. Sheikh, K., Wegdam, M., Van Sinderen, M.: Quality-of-context and its use for protecting privacy in context aware systems. Journal of Software 3 (2008)
7. Fang, S.-H., Lin, T.-S.: Cooperative multi-radio localization in heterogeneous wireless networks. Wireless IEEE Tran. on Comm. 9(5), 1547–1551 (2010)
8. Cecchini, J.: Next generation GPS-aided space navigation systems. IEEE Aerospace and Electronic Systems Magazine 17(12), 7–10 (2002)
9. Moreno, C.J., Bernardos, A.M., Casar, J.R.: An indoor location system based on RSS probability distribution estimation. Works. User-Centric Tech. and Applications, Salamanca (2008)
10. Trevisani, E., Vitaletti, A.: Cell-ID location technique, limits and benefits: an experimental study. In: Sixth IEEE Workshop Mobile Computing Systems and Applications, pp. 51–60 (2004)