Experience Map Creation by Virtual WLAN Location Estimation

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Abstract

We propose a non-cumbersome automatic location estimation method based on an easily accessible infrastructure: the 802.11 LAN. The method consists of two phases: a map-preparation phase for virtual locations of access point (VLAP) and a target client location estimation phase using these VLAPs. Using the GPS location data of nomadic probe clients as a ground truth and its captured radio signal strengths from already deployed 802.11 access points, we can estimate VLAPs in urban areas. It may be shifted from the real location but could be more reliable since it reflects real radio characteristics. We then estimate the target client location based on the estimated VLAP map in the second phase. Five estimation methods were compared and we obtained a reasonable 23.8 meter mean accuracy using the RSSI and Density-Weighted Centroid method.

1. Introduction

Human episodic memory is associated with the location and time information of memorable experiences. This location information can then be used as a helpful key when we remember our past experiences. We are developing experience-capturing systems such as a lifelog system and meeting recorders to augment human memory and support various remembering activities. As every experience more or less contains some knowledge, location-annotated collections of experiences can be used in a shared knowledge base.

The location-grounding task is, however, a tedious one as the amount of logs increase, and it generally requires an expensive infrastructure. In this paper we propose a non-cumbersome way to compute the location of a user's 802.11 client without having to know the exact location of the already broadly spread 802.11 access points. The use of radio beacons as a guide for device positioning has been investigated in many research and commercial projects, as listed in PlaceLab [1], where the radio beacons for 802.11, GSM, and Bluetooth are integrated to estimate the location of a client. It is proposed in PlaceLab to use the combination of the exact location database of access points used by organizations and the war-driving hobby location map database. We employ the same idea of using volunteers' collections of access-point beacons.

In this paper, we investigate low-cost location estimation methods employing virtual location of access points (VLAPs). We first estimate the VLAPs assisted by GPS (mapper phase), then compute the location of a user's client based on the access point (AP) beacon signals (locator phase). Five estimation methods are compared based on the received signal strength indication (RSSI) method. The experimental results indicate that the mapper obtains the best mean accuracy with the RSSI and Density-Weighted Centroid (RDWC) method, while the locator obtains good accuracy for the density independent RWC.

2. Related Works

Many location estimation methods have been proposed, e.g. the cell ID system, the time difference of arrival (TDOA) system such as AirLocation [2], and RSSI methods such as the Ekahau Positioning Engine [3] and the RADAR system [4]. However, TDOA systems require specially designed AP, while Ekahau and RADAR require fine registration step of signal strength and characteristics of APs. In our proposed system of using VLAPs, we rely on actual radio signals in the real environment where the multi-path and the wall-barrier effects are incorporated implicitly into the VLAP estimations.

3. User Location Estimation

3.1. RSSI based VLAP Estimation

We assume a mapper user will move around, hunting the AP's MAC address, its radio strength, and GPS location. As the user moves, multiple observations at different places are captured for one particular AP. We investigate the five following calculation methods to estimate a VLAP from the observed multiple signals.

(1) Maximum (Max): (x_i, y_i) for AP_k when $rssi_i$ is maximal within all observations of APs, where (x_i, y_i) is the *latitude* and *longitude* data and $rssi_i$ is the i-th radio observation of the same AP_k.

(2) Centroid (Cent): compute a centroid of whole observation of (x_i, y_i) for AP_k.

(3) RSSI Weighted Centroid (RWC): compute a weighted centroid of whole observation of (x_i, y_i) for AP_k by an inversed radio strength weight w_i derived from $rssi_i$:

$$(x, y) = \frac{1}{\sum w_i} \sum_{i=1}^{k_i} w_i (x_i, y_i),$$

$$\log_{10} w_i = (rssi_i + a) / b,$$

where a and b are computed using learning samples. In this experiment they are set to a=35.47 and b=24.42.

(4) Higher Five (HF): same as RWC except that the weight is considered only for top five *rssi* signals.

$$w_i^{HF} = \begin{cases} w_i^{RWC} & \textit{if rssi is within top 5} \\ 0 & \textit{otherwise} \end{cases}$$

(5) RSSI Density Weighted Centroid (RDWC): same as RWC except that the weight is adjusted according to the density of the samples:

$$w_i^{RDWC} = w_i^{RWC} / c_i,$$

where c_i is the number of observed points within a certain distance from the observer.

3.2. VLAP-based client location estimator

The locator uses the VLAP information, and at a given location, a user may obtain signals from several APs. The locator computes the current position using the VLAPs in similar manners to those described in Section 3.1.

4. Experimental Results

We used a Wireless Embedded Card (model 0504) built into a Panasonic CF-T1 laptop PC and a SONY GU-BT1 GPS module (5-m accuracy). The experiment was carried out on a university campus, where the density of 802.11 AP varies depending on the location. In the engineering school area, 13 APs were observed on average, while 6 APs were observed in the law school area and 3.3 APs in the green belt. We used 2,084 observations to develop a VLAP map, and other 604 point observations were applied for the estimation experiment. Table 1 shows the overall accuracy. The combination of RDWC for the mapper and RWC for the locator provides the best mean accuracy of 23.8 m with a 22 m standard deviation. Because the dense hunting of an AP by a stationary mapper moves badly the AP's location to the hunting position for RWC, the density-weighting of RDWC provided a good result to the mapper. On the other hand, the locator can be independent to the density of APs. If we break down the analysis based on AP density, the denser the area is, the better the estimation accuracy becomes. For instance, the mean accuracy was only 7.3 m in the engineering school area, where some of the indoor longitude/latitude observations were hand-labeled.

Table 1 Location Estimation Results

		VLAP estimation method				
		Max	Cent	RWC	HF	RDWC
Client location esti-mation method	Max	40.8	34.6	34.5	38.9	27.6
	Cent	34.5	31.3	31.6	33.7	26.1
	RWC	33.3	30.6	30.2	32.1	<u>23.8</u>
	HF	34.0	31.2	30.5	32.5	24.1
	RDWC	33.2	30.5	30.1	32.3	24.1

5. Conclusion

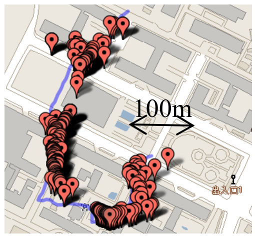

Fig. 1 Moving Route Log

The accuracy obtained in this work is fairly good for experience map creation and rough navigation, thus the estimated client location can be used in various location-aware services. Figure 1 shows an example of a walking-route log on the campus illustrated using the Googlemap toolkit. The line indicates the actual walking path.

Future work will involve a larger-scale experiment to be conducted in other city and suburban areas. The next major step in this project is to develop a wearable experience-recording system. This work is supported by the cc-Society Program, MEXT Japan.

6. References

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