Analysis and Comparison between War Driving and War Walking in Metropolitan WiFi Radio Maps

Arvin Wen Tsui[1,2], Wei-Cheng Lin[1], Hao-hua Chu[1]

[1]Department of Computer Science and Information Engineering,
National Taiwan University
No. 1, Sec. 4, Roosevelt Road, Taipei, 10617,
Taiwan
{b93067, hchu}@csie.ntu.edu.tw

[2]Information and Communication Research Lab.
Industrial Technology Research Institute
Chutung, Hsinchu County, 310,
Taiwan
arvin@itri.org.tw

ABSTRACT

War-driving is currently the most widely adopted method for building large-scale radio maps in metropolitan Wi-Fi localization. Although the human effort cost for war driving is smaller than that of war walking, its positional accuracy is also lower than that of war walking. This work compares radio maps built from war driving and walking and analyzes how selective map characteristics affect positional accuracy.

INTRODUCTION

War driving is a term first coined by Shipley [1] who drove around San Francisco to study WiFi network security problems. This war driving method of making use of the collected WiFi signal data for locating WiFi devices has been adopted by Intel Place Lab [4], Skyhook wireless [2] and others. War walking is similar to war driving except that data are collected by walkers moving around the city's sidewalks rather than drivers moving on roads. Prior studies done by Kim *et al*. [5] observed that war walking produced more accurate radio maps than war driving. The reasons are (1) a walking path is closer to APs located in buildings than its driving path; (2) Since walking speed is slower than driving speed, walking can collect more signal samples than driving.

Since 2006, we have acquired a war walking radio map covering almost the entire Taipei city, as a part of the M-Taiwan [3] project. In addition, a corresponding war driving radio map was collected. Comparison analysis focuses on two questions. (1) What is the quality (measured by positional accuracy) difference between the war driving and walking radio maps? (2) What are factors/non-factors affecting the quality difference between the war driving and walking radio maps? Findings on these questions can help developing new strategies to improve war driving.

COMPARSION ANALYSIS ON POSITIONAL ACCURACY

The war walking radio map contains signals from 103,678 WiFi APs covering 133.4 km^2 of Taipei city, which translates into a density of 777.2 APs/km^2. Given a lack of differential GPS in Taiwan and the effect of urban canyons from many high-rise buildings, GPS readings were inaccurate, hence not used in war walking. Instead, walkers carrying PDAs stood at planned calibration points to collect WiFi signals and manually keyed in a number to label each calibration point. At each calibration point, 30 samples were collected at the sampling rate of 1 HZ. A corresponding war driving radio map was collected as follows. Since drivers should not operate any device while driving, a GPS receiver had to be used. The driving speed ranged from 10 to 40 kilometers per hour. A fingerprint-based positioning engine [6] was implemented using probabilistic modeling with sliding window to prevent error propagation of APs' location estimation [5]. Additionally, interpolation [7] for locations between calibration points was used to reduce calibration efforts and/or making a dense radio map.

To test accuracy of war driving/walking radio maps, traces for walking and driving were collected throughout Taipei city. Each test trace contains some 103~964 positional estimations. Fig. 1 compares the cumulative distribution function (CDF) of positional errors between war driving and walking. Results show war walking outperforms war driving, giving twice the positional accuracy at median and 90% errors. Although war walking produced approximately twice the accuracy as war driving, the cost of producing a war walking map, measured by human working hours, is about four times that of a war driving map.

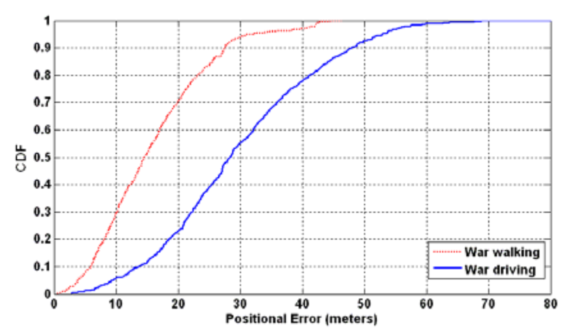

Figure 1. Positional accuracy comparison between war driving and war walking radio maps.

FACTORS/NON-FACTORS

Among various characteristics between war walking and driving radio maps, two factors were selected for further analysis: (1) the amount of data collected for a radio map and (2) the delay in GPS readings.

A. Amount of data in radio map

Does a larger number of signal data collected to build a walking map contribute to its better accuracy than a driving map? The amount of signal data has two measures: (1) the number of distinct APs and (2) the number of signal samples (each signal sample is 3-tuple of timestamp, coordinate, and received signal strength of a specific AP).

Given the area of our testing traces, 2,199 unique APs were recorded on the war walking map and 1,687 unique APs recorded on the war driving map. The number of common unique APs found on both maps is 1,291. Did the additional 500 APs in the walking map contribute to its accuracy advantage over the driving map? To answer this question, two new maps were created: (1) The “walking-reduced” map has all signal samples from the walking map while removing APs absent from the driving map; (2) the “driving-plus” map includes all signal samples from the driving map while inserting additional APs on the walking map. Fig. 2 plots CDF of positional errors from the “walking-reduced” and “driving-plus” maps, which are compared to the original walking and driving maps. Results show almost no difference between the “walking-reduced” and walking maps, and again almost no difference between the “driving-plus” and driving maps. Restated, adding or reducing these “AP differences” (between the driving/walking maps) did not affect positional error in any significant way.

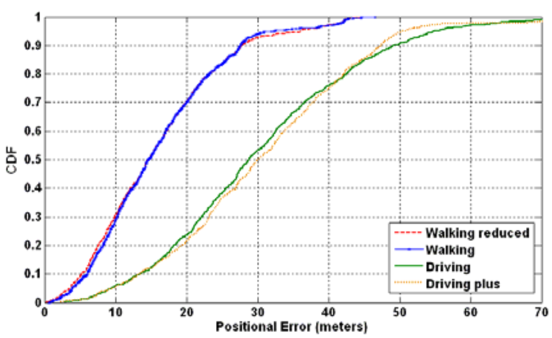

Figure 2. Effect of the number of APs on accuracy.

The numbers of samples collected by war walking/driving maps are 88,720/38,603 samples respectively. Did the additional 50,000 samples in the walking map contribute to its accuracy advantage over the driving map? To answer this question, a new map called “walking-resampled” was created by randomly dropping samples from the walking map such that it has the same number of samples as the driving map. Results show almost no difference below the 85th percentile errors. The “walking resample” map produced an increased error of 5 meters at the 90th percentile than the walking map (25 → 30 meters). In general, the effect of the number of signal samples does not significantly affect the accuracy of a radio map.

B. Delay in GPS readings

We observed a GPS delay phenomenon in which GPS readings output from the GPS receiver lagged behind the WiFi signal data for several seconds. This GPS delay did not affect our war walking, since GPS was not used. However, this GPS delay considerably affected our war driving. For example, if the delay were 3 seconds, the WiFi signal data would be mapped to a GPS coordinates 3 seconds ago. If a-driver traveled at 10 meters per second, the GPS coordinate would be off by 30 meters.

An experiment was conducted to measure the effect of this GPS delay by shifting the GPS readings ahead in the time domain (1-3 seconds), as an attempt to offset this GPS delay. Results are shown in Fig. 3. A 3-second shift gives the best result by improving the medium error from 29 meters to 24.7 meters.

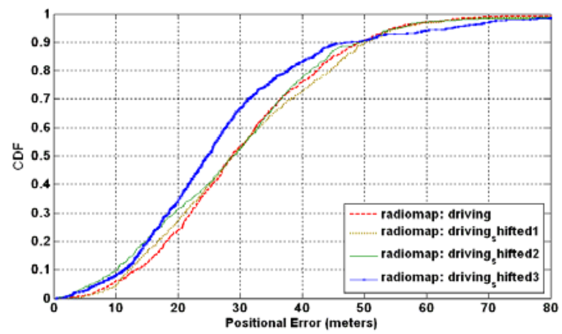

Figure 3. Effect of the GPS delay on accuracy.

FUTURE WORK

We would like to explore the effect of other map characteristics as potential factors to positional accuracy. These findings can help developing new strategies to improve war driving.

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