2014 International Conference on Indoor Positioning and Indoor Navigation, 27th-30th October 2014

Challenges and Strategies for Wireless Positioning

Sangwoo Lee
Department of Electronics and Computer Engineering
Hanyang University
Seoul, Korea
lswoo@hanyang.ac.kr

***Abstract*—This abstract addresses challenges and strategies for wireless positioning. The anisotropic network localization problem and the solutions are discussed for wireless sensor networks. Applications of Bayesian filters are introduced to track positioning parameters in global navigation satellite systems. Radio map-based positioning solutions robust to the received signal strength variation are also described.**

***Keywords*—wireless positioning; network localizatoin; satellite system; Bayesian filter; radio map-based positioning**

I. Introduction

My doctoral research has been carried out on wireless positioning in a variety of wireless systems. In this abstract, my published and on-going work accomplished during my Ph.D. period is briefly presented. The network localization problem is investigated in the range-free context. Bayesian filtering algorithms are introduced to solve the satellite signal tracking problem in the presence of interference. Bayesian filter-based approaches are described to mitigate the effect of received signal strength (RSS) variation and to enhance the accuracy of RSS radio map-based positioning.

II. Range-Free (Connectivity-Based) Localization for Wireless Anisotropic Networks

Range-free localization is an effective approach for highly resource-constrained and large-scale wireless sensor networks. It is expected that this approach is also applicable to other wireless networks in which nodes are allowed to directly communicate with each other. Instead of using signal measurements, the hop count of the shortest path between nodes is used to estimate the distance between them. Conventional range-free algorithms were developed for isotropic networks where the shortest paths of any node pairs are nearly linear-shaped. However, in practice, the shortest paths are detoured from the linear-shaped paths due to different anisotropic factors.

A. Approximate Shortest Path-Based Localization

In isotropic networks, it is assumed that the length of the shortest path for packet delivery from one to another approximates their geographical distance. However, this assumption does not hold in anisotropic networks where the shortest path is detoured. If global connectivity information is available, it is possible to estimate the shape of the path, and

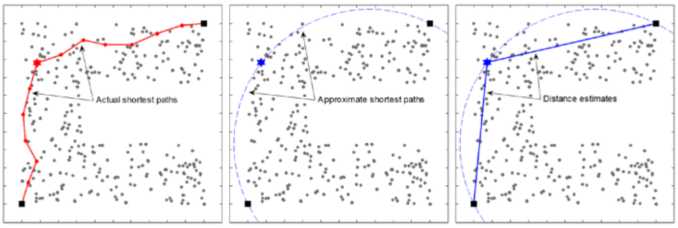

Fig. 1. Approximate shortest paths and distance estimations with a circular-shaped virtual hole.

more accurate distance estimates are obtainable. However, the requirement of global connectivity information brings an extremely large communication overhead and reduces the network lifetime.

A range-free localization algorithm with the shortest path approximation is presented in [1]. The idea of this approach is illustrated in Fig. 1. By measuring the deviation in the hop count between the direct and shortest paths of an anchor pair, each node detects if the shortest paths to the anchors are detoured from their direct paths. Then, the shortest paths are approximated as the boundary of a circular-shaped virtual hole based on the path deviation. The node estimates the distances to the anchors by taking into account the extent of the detour of the approximate shortest path. Hence, each node is able to acquire the distance estimates to anchors with local connectivity information in anisotropic networks.

B. Pascal's Triangle-Based Localization

The main idea of the Pascal's triangle-based localization (PTL) algorithm [2] is to estimate the distance from a normal node to an anchor based on the location candidates of the node. Based on the relationship between the average hop progress and the average one-hop internodal distance, the relative location candidates of a normal node with respect to an arbitrary anchor pair are derived with the probabilities of the node being at the location candidates. Then, the node estimates the distances to the anchors as the mean distances from the location candidates to the anchors. A combination of the location candidates of the intermediate nodes can be one possibility of the shortest path between the node and the anchor. With different combinations of the candidates, the PTL algorithm is able to estimate the distance between the node and the anchor by considering multiple possible paths for the shortest path with their possibilities.

C. Reliable Anchor Pair Selection

Reliable anchor selection-based range-free algorithms solve the problem by selecting and using reliable anchors, which are considered to have undistorted shortest paths to the normal nodes. However, the previous algorithms highly depend on the nearest anchor that is only few hops away from the normal node. Moreover, they exploit the distance estimation method used for isotropic networks. Hence, a large number of uniformly deployed anchors are required, and the distance estimates become inaccurate when the shortest paths to the reliable anchors are detoured.

A reliable anchor pair selection (RAPS) is developed in [3] to overcome the drawbacks of the previous algorithms. In the RAPS algorithm, each normal node selects reliable anchor pairs based on the average hop progresses. The RAPS algorithm estimates the distances to the reliable anchors by taking into account the geometric approximation of the node location with respect to the anchor pairs. The RAPS algorithm enables a normal node to derive the average hop progress for the shortest paths to an anchor pair. Since the anchors' location and hop count information is only required. The RAPS algorithm is able to determine whether or not the shortest paths are detoured and to select reliable anchors with the reduced communication overhead compared to the previous algorithms.

III. Positioning Parameter Tracking with Bayesian Filter in Global Navigation Satellite Systems

For the positioning purpose, tracking time-delay or time-of-arrival (TOA) of a satellite signal has been challenging in global navigation satellite systems (GNSS). Recently, applications of recursive Bayesian filters have been addressed for high-precision GNSS signal tracking under interfering signals. In particular, the use of particle filters has been emphasized to provide outstanding performance in nonlinear and non-Gaussian settings.

A. Particle Filter-Based LOS and Multipath Tracking

From the Bayesian filtering perspective, the GNSS signal tracking problem in the presence of multipath is defined as the problem of estimating the overall parameters of all incoming signals including line-of-sight (LOS) and multipath signals by constructing the posterior probability density function of the state given all available measurements [4]. Particle filters characterize the posterior density of the state with a set of random particles. Considering array antenna receivers, each particle (a possible candidate of the state) is composed of TOAs, direction-of-arrivals (DOAs), and complex amplitudes of the LOS and multipath signals. The particle evolves according to the state evolution model, and the corresponding weight is computed with the signal measurement. The signal estimates can be determined based on the minimum mean square error criterion.

B. Particle Filter-Based LOS Tracking with Beamforming

Although the previous approach enhanced the TOA tracking accuracy in multipath environments, this approach may not function well due to the signal model mismatch when multhpath and interference signals coexist. Also, since the main concern is to estimate the LOS signal's parameters, it is inefficient to estimate the parameters for unwanted signals. Receive beamforming techniques can be exploited for the computational efficiency and the signal model mismatch evasion in the Bayesian filtering framework. With the help of receive beamforming, the GNSS signal tracking problem can be defined as the problem of tracking the LOS signal only while suppressing the other signals [5].

IV. RSS Variation Mitigation with Recursive Estimators for RSS Radio Map-Based Positioning

RSS significantly varies by environmental changes, device types, device orientations, and other factors. Hence, even though the device is placed at a same location, different RSS measurements are obtained. In other words, currently obtained RSS measurements are different with the ones in the RSS radio map. The RSS variation problem degrades the accuracy of RSS radio map-based positioning such as fingerprinting positioning. To solve the RSS variation problem, the RSS measurement is modeled as a linear transformation function in terms of RSS variation parameters. The recursive least square estimation and particle filter are applied to estimate the RSS variation parameters. Then, RSS measurements are recovered with the parameter estimates as seen in Fig. 2, and the recovered RSS measurements are used for radio map-based positioning.

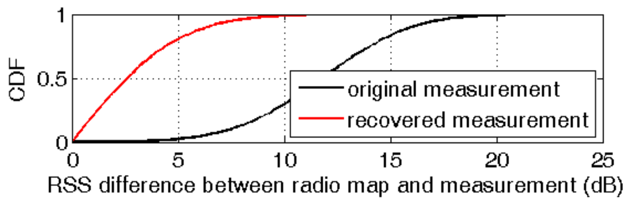

Fig. 2. RSS variation is alleviated by estimating the variation parameters.

Acknowledgment

I would like to thank Prof. Sunwoo Kim, who is my Ph.D. advisor, for providing the opportunities to extend the depth and breadth of my research.

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