

DOCTORAL THESIS

Advances in Wifi Fingerprinting Positioning System: Anchor Optimization, Fingerprint Processing and Theoretic Error Bound Analysis

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Abstract

With the development of Indoor Location-based Services (ILBSs), there have been increasing demands on high-accuracy indoor positioning systems. Recently, WiFi fingerprinting positioning system has been widely studied due to the pervasive infrastructures. However, it still faces some challenges, such as the anchor optimization problem, processing of raw fingerprints, and the assessment of theoretical location accuracy, etc. Therefore, in this thesis, we study these mentioned challenges to improve the location accuracy, system efficiency and robustness.

First, we conduct an Access Point (AP) deployment optimization based on the projection-induced knowledge. APs, as the anchor nodes in user aimed fingerprinting positioning system, have significant impact on location accuracy. We construct an objective function aiming at decreasing big error cases and then solve it from the projection perspective rather than search algorithms. Besides, an outlier detection based on K-Nearest Neighbors (KNN) graph is operated on fingerprints before the solving procedure.

Second, we propose a joint compressive sensing (CS) kernel optimization and outlier detection scheme in rogue AP aimed fingerprinting positioning system. In fact, the designed CS kernel is the result of monitor (anchor node) optimization. The scheme consists of three steps: i) coarse localization: a novel Object Weighting Affinity Propagation (OWAP) clustering method is proposed to group the offline fingerprints; ii) CS kernel optimization: the minimum number of required monitors is deduced and an Equiangular Tight Frame (ETF) based monitors selection scheme is presented; and iii) joint fine rogue AP positioning and outlier detection: a formulation of an improved CS based sparse recovery model is proposed. This scheme achieves higher location accuracy and increases the localization robustness.

Third, for large-scale application scenarios, the raw fingerprints will bring the storage problem and computational complexity due to high dimensionality. Hence, we present a feature extraction algorithm using a manifold learning called T-distributed Stochastic Neighbor Embedding (TSNE) which extracts these non-linear fingerprint features and reduces the dimensionality of fingerprint database simultaneously. Then an out-of-sample extension method is proposed to process the online records to achieve the same dimensionality as the reduced database. Furthermore, when determining the proper dimensionality, we utilize an intrinsic dimensionality estimation method to obtain the best dimensionality in advance.

Lastly, theoretical analysis on location accuracy is a significant work since it can present the factors affecting the location accuracy mathematically and inversely serve as a guideline to optimize the positioning system. Hence, we construct a novel derivation model involving the grid size to analyze the error bound from the

perspectives of the signal measurement and positioning algorithm. From the former perspective, the error bound is analyzed under two cases: specific and non-specific signal distributions. For the first case, we utilize the traditional knowledge of Cramér-Rao Lower Bound (CRLB) to re-derive the theoretical error bound. For the second case, a Gaussian-Markov theorem method is introduced to conduct derivation. From the latter perspective, we analyze the error bound of the widely used KNN algorithm, based on which a novel adaptive KNN algorithm is designed and it has improved the location accuracy about 20%.