Application of Geostatistical Techniques for Spatial Interpolation of Location Fingerprints

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Abstract

Techniques such as triangulation and trilateration have been used along with RSSI, TDOA etc. for localization in outdoor scenarios. However in densely urban areas where many obstacles exist, multipaths are dominant resulting in the above techniques to be unreliable. Fingerprint-based localization may prove to be advantageous in these scenarios [1]. Location fingerprints should be collected from as many areas as possible, but this is not feasible due to time and space constraints. One approach to solve this problem is to perform spatial interpolation on the collected fingerprints to estimate the fingerprint at an arbitrary location. This research aims to provide insight on effect of the fingerprint collection intervals on estimation accuracy by performing Monte Carlo simulations under various urban environments and conditions.

Popular spatial interpolation techniques include linear interpolation, nearest-neighbor interpolation and spline interpolation. In this research, we compare a technique called Ordinary Kriging (OK) [2], which is a commonly used technique in the field of geostatistics, with several other common interpolation techniques.

The basic idea behind Kriging-based spatial interpolation is to apply weights to already observed values at surrounding locations, and the weights are calculated according to spatial covariance values. It is assumed that propagation characteristics from points located close to each other have higher correlation than points located far away from each other. Therefore, the spatial covariance will be a decreasing function over distance, and Kriging will apply larger weights to observed values located close to the interpolation point. In Ordinary Kriging, it is assumed that the observed values (fingerprints) can be expressed as the summation of a constant local mean and the residual. The expectation of the residual is assumed to be zero, and covariance of the residual between two locations is assumed to be stationary and only a function of distance.

The whole interpolation process can be divided into several steps. The first step is to estimate the spatial covariance function from observed location fingerprints. Then second step is to fit the estimated covariance function with some basic covariance models. Finally, weights are calculated by solving a set of linear equations based on the covariance model obtained in the previous step.

In this research, we propose and compare several variants of OK which may be able to capture the spatial correlation structure of the environment more accurately. The channel impulse response (CIR) and RSSI are utilized as location fingerprints. Ray-tracing simulation is conducted to obtain location fingerprints at various urban environment scenarios. Then the estimation error of several spatial interpolation algorithms is compared with respect to several factors such as fingerprint collection interval, density of buildings in the environment, and also robustness against multipath fading.

References

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