Building radio map with geostatistics

***Abstract*—Building a WiFi radio map is often useful to network engineers in order to understand the network covarage. In this short report we play a bit with geostatistics to create such radio map for an IEEE 802.11ac network deployed in an open-space.**

I. Introduction

Building a radio map is often important for understanding the coverage area. Geostatistical tools such as Kriging, in turn, are useful for estimating the values at unknown locations. In this short report, we present the results for the interpolation of WiFi signal using Ordinary Kriging. We first present the basic mathematics behind the Simple Kriging and then show the results for the interpolation of real data.

II. Data collection methodology

To collect the data, we have used two identical WiFi adapters (supporting IEEE 802.11ac standard), two microcomputers, and a GPS receiver. We have configured the adapters with maximum output power (20dBm) and used 3dBi omni-directional antennas.

We have logged the GPS coordinates and WiFi signal strengths every 1 second and stored the collected data in the file. We have chosen large enough open-space outside of the city to collect the data so that the interference at 5GHz range was minimized.

III. Data processing and basic results

The first step in geostatistics is to build the variogram. We have used the omni variogram. The basic formula for the variogram:

$$\gamma(h) = \frac{1}{2N(h)} \sum |z_i - z_j|^2$$

Once the emprical variogram is constructed the analysis (for Simple Kriging) proceeds as follows:

$$Z^*(x_0) = \sum \lambda_i Z(x_i)$$

In order to find all λ's we do the following. We want to minimize the expected value for square differences of predicted and actual values for signal strengths:

$$\min E[(Y_0^* - Y_0)^2], s.t. Y = Z - \mu_Z$$

By expanding the above equation we get:

$$\min E[(Y_0^*)^2 - 2Y_0^* Y_0 + (Y_0)^2]$$

And finally, by using the property of the expected value we get:

$$\min E[(Y_0^*)^2] - 2E[Y_0^* Y_0] + E[(Y_0)^2]$$

By substituting the Y^* in the equation and rearranging the terms a bit:

Fig. 1: WiFi base station

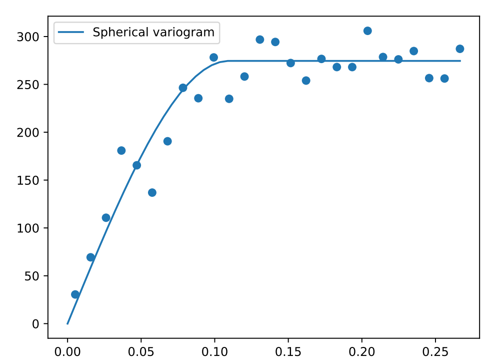

Fig. 2: Fitted variogram

$$\min \sum_{i=1}^{n} \sum_{j=1}^{n} \lambda_i \lambda_j E[Y_i Y_j] - 2\sum_{i=1}^{n} E[Y_i Y_0] + E[(Y_0)^2]$$

But since the values have 0 means we can rewrite the above equation as follows:

$$\min \sum_{i=1}^{n} \sum_{j=1}^{n} \lambda_i \lambda_j \sigma_{ij} - 2\sum_{i=1}^{n} \lambda_i \sigma_{i0} + \sigma_0^2$$

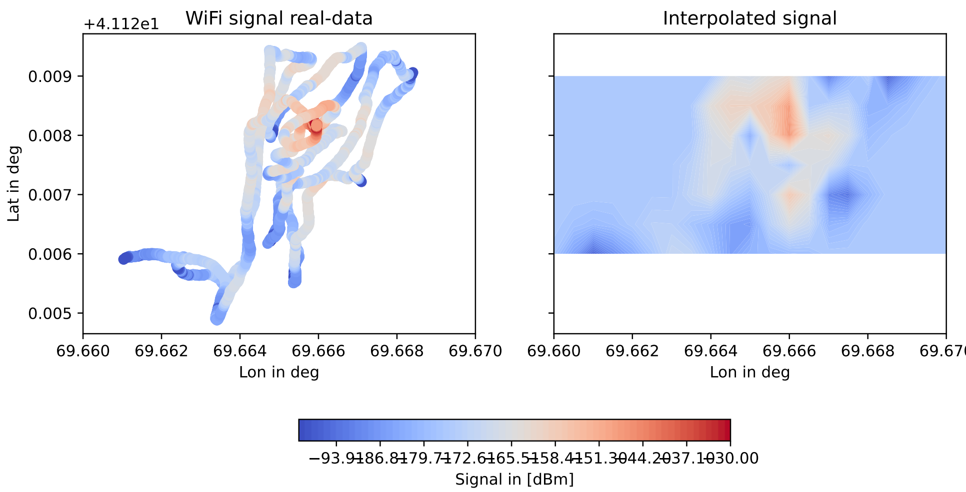

Fig. 3: Actual and predicted data

But we want to minimize the above expression so we need to find the derivative of the above formula and equate it to 0. We then need to solve the following system of equations to find all λ's:

$$\begin{bmatrix} \sigma_{11} & \dots & \sigma_{1n} \\ \vdots & \ddots & \vdots \\ \sigma_{n1} & \dots & \sigma_{nn} \end{bmatrix} \begin{bmatrix} \lambda_1 \\ \vdots \\ \lambda_n \end{bmatrix} = \begin{bmatrix} \sigma_{10} \\ \vdots \\ \sigma_{n0} \end{bmatrix}$$

To compute the variogram and predict the values using Ordinary Kriging we have used the GSTools library [1]. We have fitted spherical variogram into the data. The result is shown in Figure 2.

We then estimated the values for signal strengths at unknown locations using the spherical variogram and Ordinary Kriging. The results are shown in Figure 3.

IV. Conclusions

In this short report we have demonstrated how to apply ordinary Kriging to interpolate the values of WiFi signal. We believe that given representative dataset Kriging can be used to build quite accurate radiomaps.

References

[1] S. Müller and L. Schüler. GSTools v1.3: a toolbox for geostatistical modelling in Python,. *Geosci. Model Dev.*, 15:3161—-3182, 2022.