

Review

The manuscript presents an approach to interpolation that first uses a constrained biharmonic equation interpolation to de-trend the data on a large scale, and then uses a constrained sequential Gaussian simulation (cSGS) method to model the residual. Uncertainty is propagated from the first to the second. As far as I can tell the contribution here is the combined use of biharmonic interpolation and cSGS to achieve an interpolation that can incorporate different types of non-Gaussian constraints on the surface.

I recommend that the manuscript be rejected because the cSGS method used is not justified and cannot be seen as safe for this type of application.

To begin with, there are many approaches to applying constraints to Gaussian process analysis, the authors do not cite or discuss any, not even for the one they use. My own search did not uncover anything that provides either theoretical convergence results or empirical evidence that the cSGS method used here is reliable in general or for any specific special cases.

SGS is used to sample a finite point surface z from a Gaussian process distribution $P(z)$, which is essentially a large multivariate Gaussian. SGS breaks this up into a sequence of univariate sampling problems by taking advantage of the fact that,

$$P(z_1, z_2, \dots, z_N) = P(z_1)P(z_2|z_1)P(z_3|z_1, z_2) \dots P(z_N|z_1, \dots, z_{N-1})$$

If we have a collection of constraints $t = (t_1, t_2, \dots, t_N)$, each associated with one location, the distribution to sample from becomes,

$$P(z_1, z_2, \dots, z_N|t) = P(z_1|t)P(z_2|z_1, t)P(z_3|z_1, z_2, t) \dots P(z_N|z_1, \dots, z_{N-1}, t)$$

The cSGS method described in this manuscript implicitly simplifies this to,

$$P(z_1|t_1)P(z_2|z_1, t_2)P(z_3|z_1, z_2, t_3) \dots P(z_N|z_1, \dots, z_{N-1}, t_N)$$

This is invalid because in general,

$$P(z_j|z_1, \dots, z_{j-1}, t_j) \neq P(z_j|z_1, \dots, z_{j-1}, t)$$

These two can be very different distributions and it should be easy to imagine situations where the difference can be made arbitrarily big. This type of cSGS can be expected to produce more serious artifacts as more constraints are added. The only case where one could expect the effects to not be serious is where the constraints are either very uninformative (after de-trending), or where they all enforce the same simple thing everywhere (e.g. limited to enforcing non-negativity at all locations).

The authors do not present this as an approximation, nor do they discuss the problems that can arise from it. This leads to two possible conclusions, either they are unaware that it is an approximation, or they are but chose not to discuss the implications.

The manuscript misrepresents the significant computational challenges that come with incorporating non-Gaussian constraints on Kriging/Gaussian-process analysis.

The results comparing results on raw and de-trended data cannot be considered meaningful because both results are based on a sampling method for which we have no way to know how defective they may be individually.