

Research Question: How accurately can a surrogate model (Kriging) predict the maximum stress response of the sun sail structure?

1. Which Design of Experiments was selected/developed?

The design selected for the Surrogate FEM model involves using **Latin Hypercube Sampling (LHS)** combined with an optimality criterion based on repulsive force between the sample points. The process was implemented as follows:

- Initial **LHS** generates 200 sample points, ensuring that each input variable is sampled evenly across its range.
- We use an optimality criterion G defined below which, in a physical analogy, is the sum of the norm of the repulsive forces if the sample points are considered as electrically charged particles.

$$G(\mathbf{L}) := \sum_{i=1}^N \sum_{j=i+1}^N \frac{1}{\|\mathbf{x}_i - \mathbf{x}_j\|^2}.$$

- The initial LHS is then fed into a Genetic Algorithm which builds a population of 50 LHS samples, and runs for 5000 iterations, optimizing using the criterion G explained above to generate the optimal LHS.

The final design consists of 200 points, which are suitable for surrogate modeling.

Source: M. Liefvendahl, R. Stocki, A study on algorithms for optimization of Latin hypercubes, <https://doi.org/10.1016/j.jspi.2005.01.007>

2. How are the experiments structured within the file(s)?

The experiments are structured in a **CSV file** as follows:

Rows correspond to a single sample. Columns correspond to the features:

sigma_mem_y – Membrane rupture stress (Lognormal)

f_mem – Snow load on membrane (Gumbel)

sigma_mem – Membrane pre-stress (Lognormal)

E_mem – Membrane Young's Modulus (Lognormal)

nu_mem – Poisson's ratio of the membrane (Uniform)

sigma_edg – Edge cable pre-tension (Lognormal)

sigma_sup – Support cable pre-tension (Lognormal)

The data is stored in the same physical units as specified, as required by the model.

3. What tools (functions, packages, etc.) were used for generation?

Numpy for matrix calculations

Pandas for converting to csv files

Scipy.stats to get distribution data

Geeks for Geeks and Gemini was used to implement the genetic algorithm.

Verification:

LHS Sample Verification Against Marginal Distributions

