Multivariate Adaptive Regression Splines.

A surrogate modelling method

Group 7, 02.12.2025

The problem

Why bother with surrogate models?

- The sun-sail model has 690 finite elements, each contributes equations to a larger global system.
- Running a full finite element model is computationally expensive.

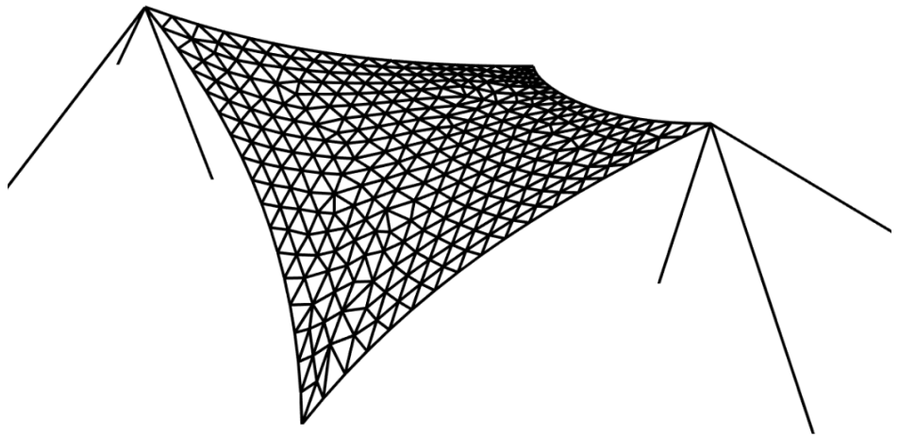

Fig 1. SunSail

So… we need a surrogate model — a cheaper, faster, friendlier stand-in.

Multivariate Adaptive Regression Splines (MARS)

- A non parametric regression method.

- At the core of MARS are basis functions:

$$f(x_i) = \sum_{j=1}^{k} c_j B_j(x_i) + \varepsilon_i$$

- Basis functions in MARS are called Hinge functions.

$$(x - t)_+ = \max(0, x - t),$$

$$(t - x)_+ = \max(0, t - x)$$

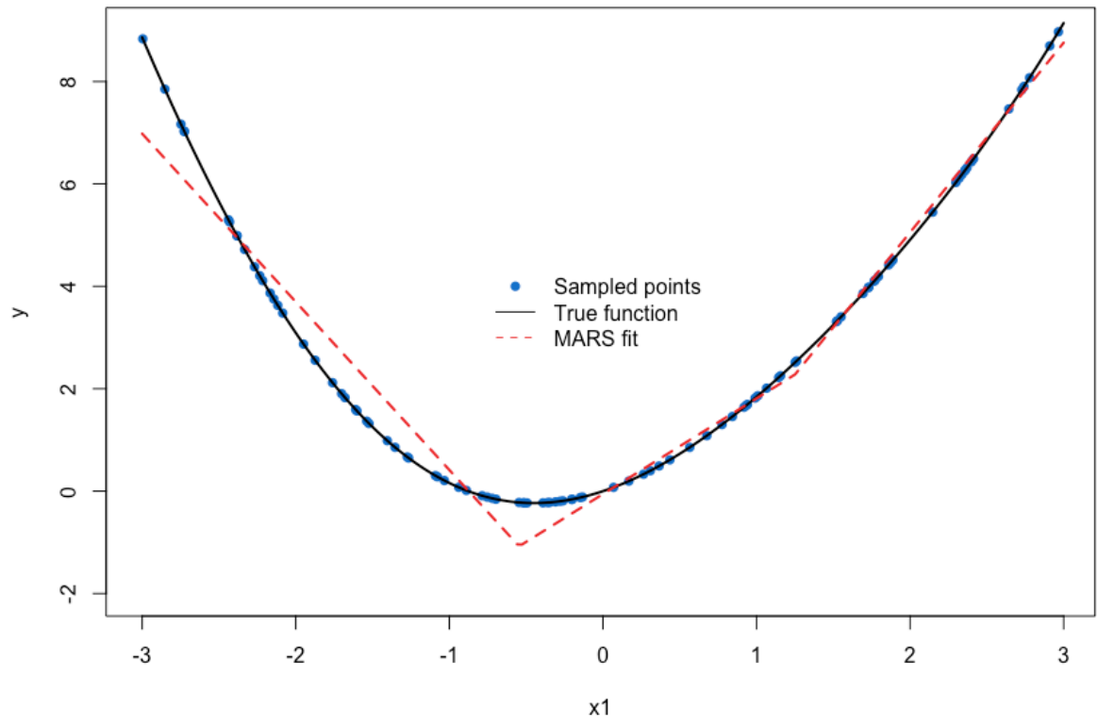

Fig 2. MARS approximation of y = sin(x) + x^2

Hinge functions allow MARS to bend the model locally at different knot positions.

The Algorithm ⚙️

- MARS starts with a minimal model containing only an intercept
- In the forward step, it considers many candidate hinge functions at different knot positions and adds the one that improves the model fit the most
- Continue until you reach a very flexible model with many basis functions
- Then the backward pruning step removes basis functions one at a time, removing the least helpful one (model selection score via Generalised Cross Validation)
- Ends when the best balance between fit and complexity is found
- This forward–backward process balances flexibility and interpretability.

Why MARS is a Strong Candidate for Sun-Sail model

Strengths

- Handles nonlinear stress-parameter relationships
- Works well with moderate datasets
- Automatically detects interactions
- More Interpretable than GP
- Successful track record in engineering surrogate modelling literature

Limitations

- Not smooth like GP
- Might require tuning for number of basis functions