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# A variable-rate sampling framework for efficient aerodynamic data sampling in CFD applications

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**Abstract:** Simulations in aerospace engineering require models that capture behaviour of subsystems that are high dimensional, nonlinear and which yield solutions valid in a subset of the domain. Whilst using surrogate models implemented as function approximators satisfy run-time requirements, obtaining the data to build the surrogate models can be expensive. For example, obtaining high-fidelity aerodynamic data via computational fluid dynamics (CFD) is often limited by the significant computational cost of sampling the solution space. Sampling strategies that reduce the computational cost of building the surrogates are therefore attractive.

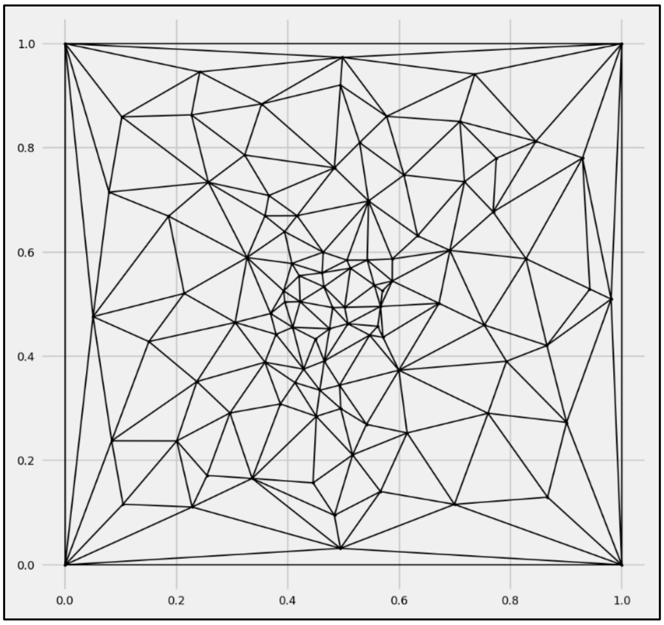

**Figure 1: Error-based heuristic sampler of single peak function with 100 samples.**

This work represents an adaptive sampling technique that leverages domain knowledge and error-based heuristics to adaptively focus computational effort where it is most needed in the context of developing a model of a system across parameter variations. The adaptive sampler evaluates the error between predicted and actual data points of the solution space, then determines the next sampling point based on the level of error surrounding each of the simplices in the triangulation. The advantage of this method is two-fold; first, this concentrates the sampling in regions of high function variability – such as near aerodynamic stall – whilst reducing unnecessary computation in linear regions, and second, this utilises the already calculated data points to guide future sampling priority.

For initial testing, a sample function with a single peak central to the solution space was sampled with the error-based heuristic and a naive grid-based sampler for comparison. The mesh developed by the heuristic sampler is shown in Figure 1, demonstrating a concentration of sample points in the centre of the solution space where the function variability would be highest.

Applying the new sampler to an X15 (a hypersonic NASA experimental aircraft) aerodynamic model allowed evaluation of the sampler against a domain-specific dataset. A sweep over angle of attack and Mach number for 72 sample points was computed using OpenVSP, providing a function relating the lift and drag to angle of attack, and Mach number via piecewise interpolation. The sampler showed improvements for small sample sizes (~16), but the results highlighted a limitation to the current implementation of the error-based heuristic sampler. The use of a Delaunay with initial points at the vertices of the solution space followed by subdivision of simplices at their barycentre inhibits the addition of points along the boundary itself. This causes high levels of error along the boundary where there is strong non-linearity. Refinement of the sampling logic to account for sampling along the boundary between valid and invalid regions of the solution space is the focus of ongoing work. The results show that the proposed algorithm is effective in reducing the burden of sampling for surrogate generation in a general setting and is straightforward to apply and control via specified error tolerances.

***Keywords:*** *Adaptive sampling, surrogate modelling, aerodynamic data, computational fluid dynamics, error analysis*