Response Surface Evolution Applied to Data Fusion

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Data Fusion

Data Fusion attempts to take advantage of low cost results to help build a surrogate response surface model (RSM) of fewer more accurate results. Low cost results are used to provide an approximation of the shape of the response surface. Fewer high cost results are then used to build an approximation of the correction factor needed to produce an equivalent high accuracy surface. This method is shown in Figure 1 for the optimisation of the lift to drag ratio (L/D) of an aerofoil section with respect to 2 orthogonal basis function shape parameters.

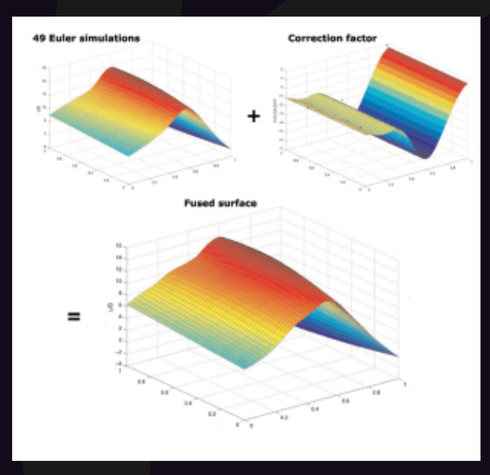

Figure 1 Data fusion

10 high cost Reynolds-averaged Navier-Stokes (RANS) calculated points have been fused to 49 low cost Euler calculated points. The total CPU time was 126hrs (32hrs 40min Euler & 93hrs 20min RANS). In contrast, the RSM in Figure 2 built from 49 high cost points, required 457hrs 20min. Clearly, data fusion can offer large time savings - in this case 73% - relative to high cost high fidelity RSMs.

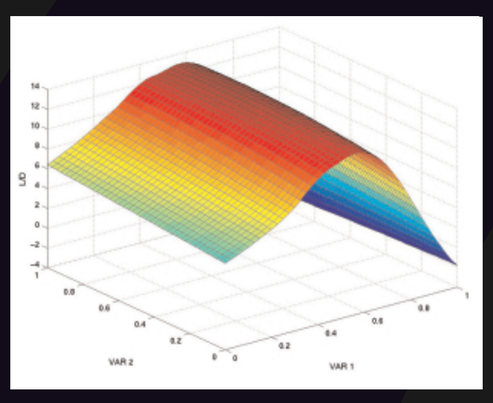

Figure 2 RSM built entirely with high cost data

Evolution

Since low cost (and relatively low fidelity) simulations are, effectively, employed within data fusion to provide an approximation to the shape of a higher fidelity response surface, further speed-up enhancements should be possible using RSM evolution monitoring techniques. For example, low cost CFD simulations can be terminated when the associated gradient residuals have sufficiently converged and updating of the fused surface can commence when the gradient residuals of this surface have converged. This process is outlined in the strategy shown in Figure 3.

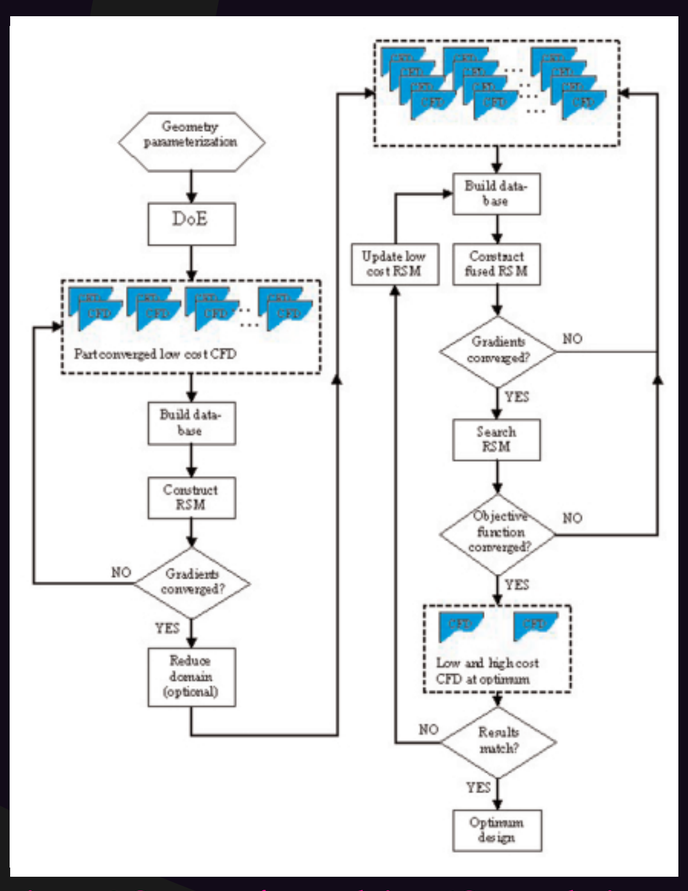

Figure 3 Strategy for applying RSM evolution to data fusion

The gradient residuals for the Euler calculated L/D of the aerofoil optimisation converge after only 100 iterations. Despite the appearance of irregularities in the convergence between 225 and 300 iterations (see Figure 4), the general trend is still that predicted by the gradient residuals.

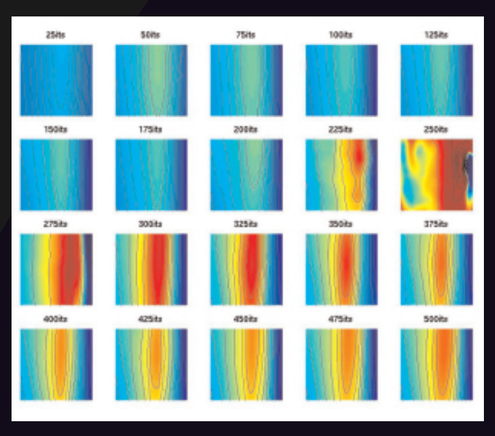

Figure 4 Euler RSM evolution

Figure 5 shows an approximation to the high fidelity RSM produced by fusing 10 high cost RANS simulations with the RSM yielded after 100 iterations of the low cost Euler simulations. The time taken to produce the Euler results has been reduced to just 78mins, giving a total time saving of 79% over the high cost RSM. The fusion correction factor (see Figure 6) is very different to that for the fully converged case and displays that the Euler simulations were far from convergence. However, they are closer to the RANS data at this stage. Comparing the fully converged fusion (Figure 1), the evolution fusion (Figure 5) and the high cost RSM (Figure 2), it is seen that the evolution surface is a closer approximation to the high cost RSM. The correlation between the evolution fusion and the 49 RANS simulations used for the high cost RSM is higher with an R^2 value of 0.9980 compared to the fully converged fusion with R^2=0.9845.

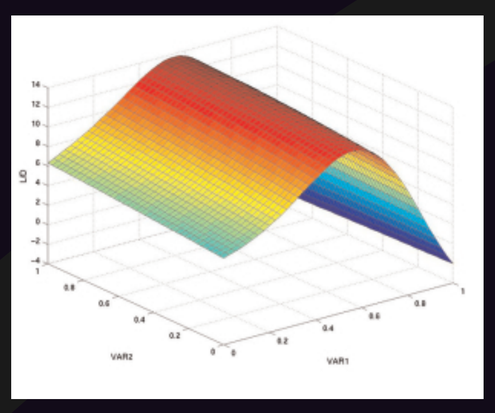

Figure 5 Fused RSM from evolution

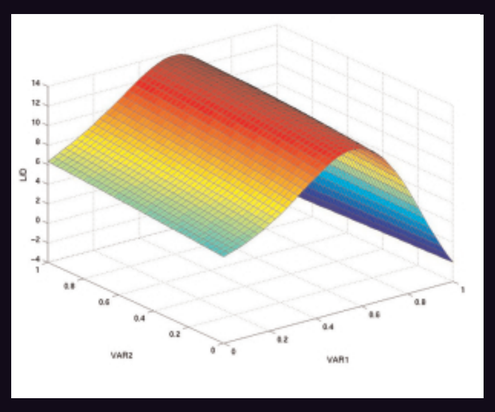

Figure 6 Evolution fusion correction factor

Evolution may be applied further to reduce the domain of RANS simulations to the Euler predicted region of the optimum. 10 points could be clustered in this region to give greater accuracy or fewer points may be used to save time. RSMs are usually updated at the optimum after a search of the surface has been performed. These updates can be performed earlier if the gradient residuals are monitored to show when the surface has stabilised and the region of the optimum is known. Figure 7 shows the evolution of the fused RSM for every 250 iterations of the RANS simulation and displays that the region of the optimum is visible at an early stage in the convergence of the simulations.

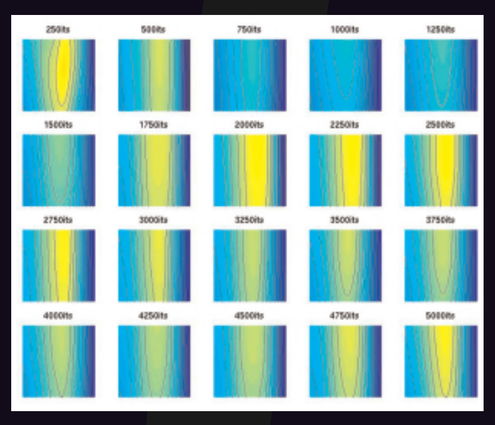

Figure 7 Fused RSM evolution

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