Taxonomy of a Design Process

This article may be found at
http://www.soton.ac.uk/~cedc/posters.html

Carren Holden
BAE SYSTEMS
Advanced Technology Centre,
Sowerby Building,
PPC 267, PO Box 5,
Filton, Bristol,
BS34 7QW
and University of Southampton
Computational Engineering and
Design Centre.
Email:
carren.holden@baesystems.com

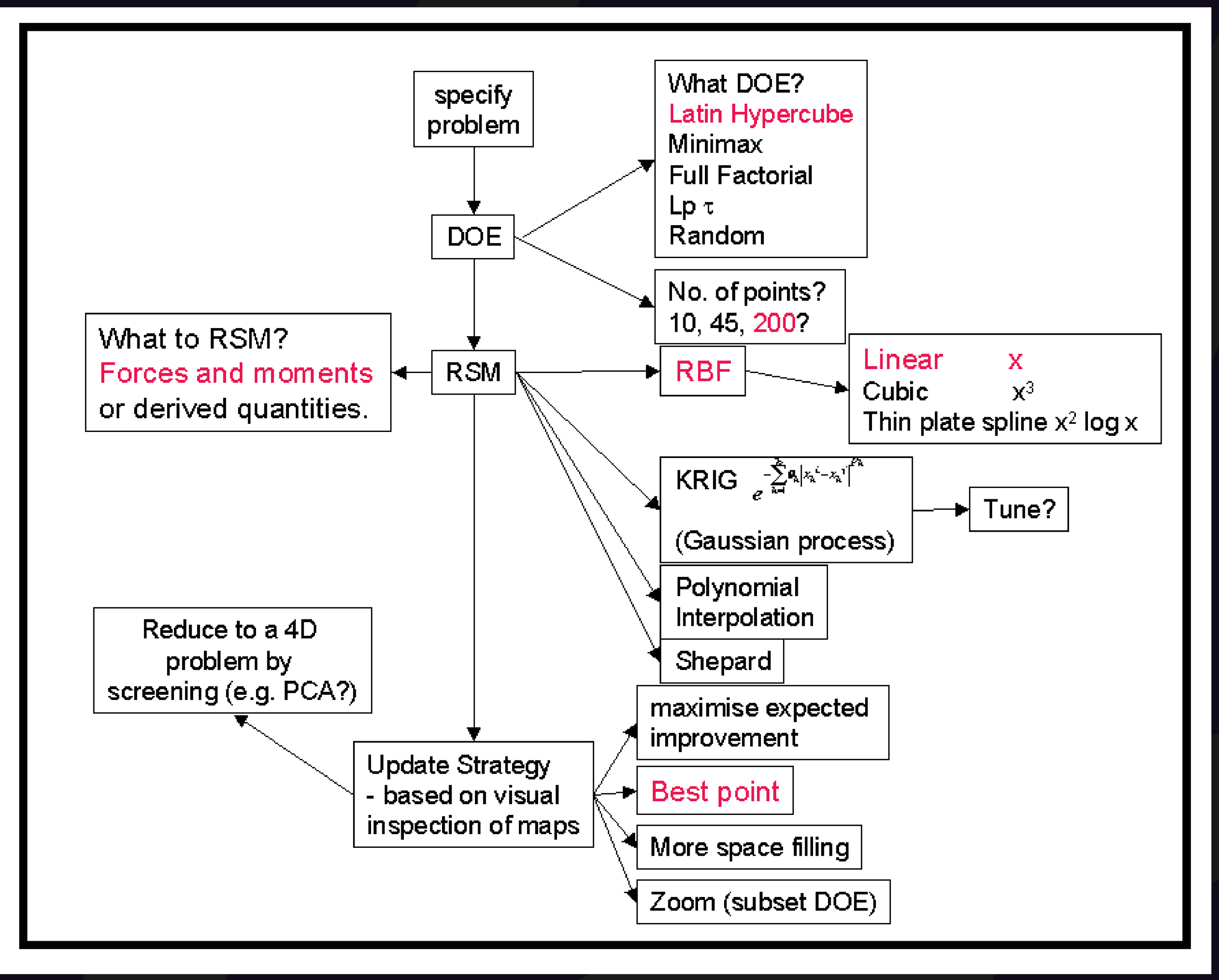
UTP for design

CEDC

And so that the aircraft is trimmed:

$$C_{M,total} = C_{M,l.e} + C_{L,wing}.h$$

$$\Rightarrow \frac{C_{L,total} + a_3}{-\dfrac{C_{M,l.e.}\,c}{\cos\alpha\,.h} - C_D \tan\alpha + a_3} = 1.0$$



In a sophisticated design process, such as for instance used in an aircraft aerodynamic design, a four dimensional design problem is specified in terms of an objective function and constraints, which require an expensive three-dimensional unstructured Euler method evaluation.

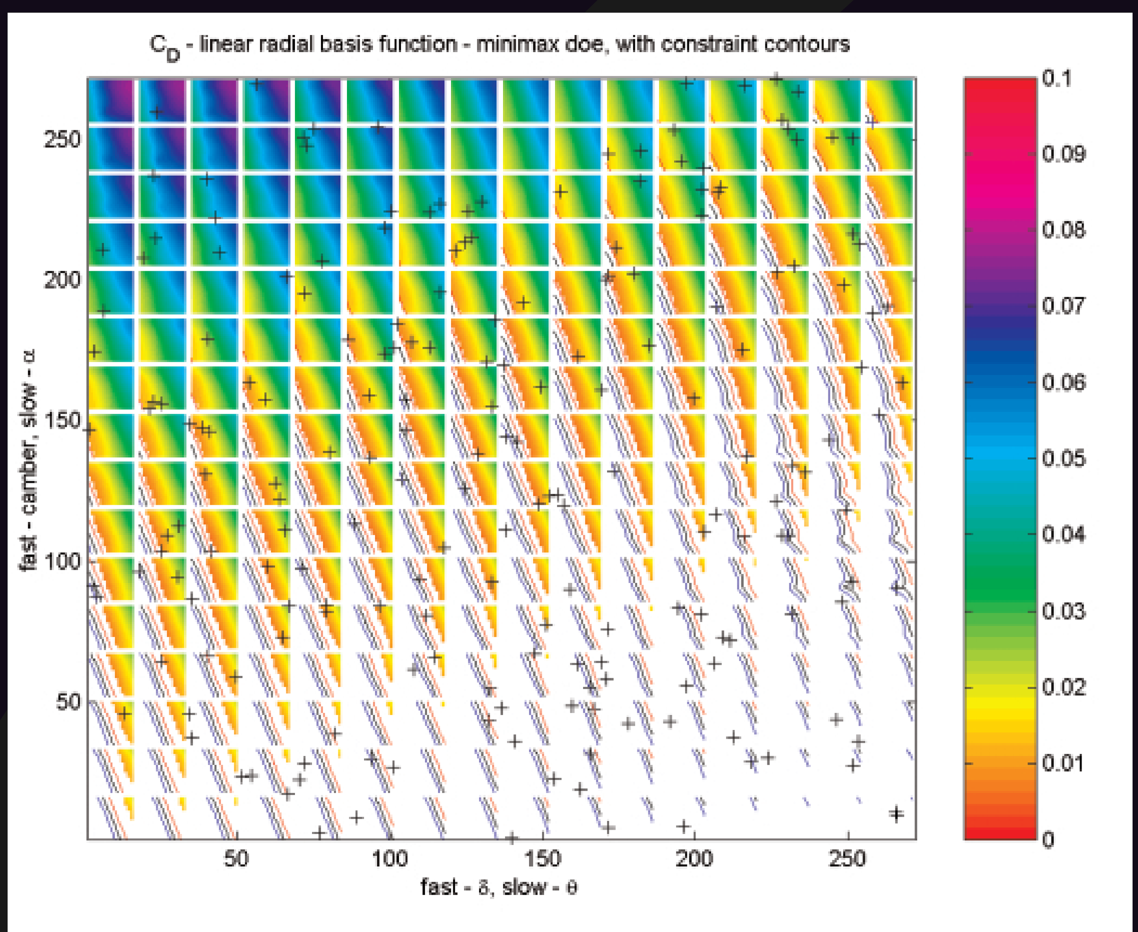
The problem to be solved is specified as follows:

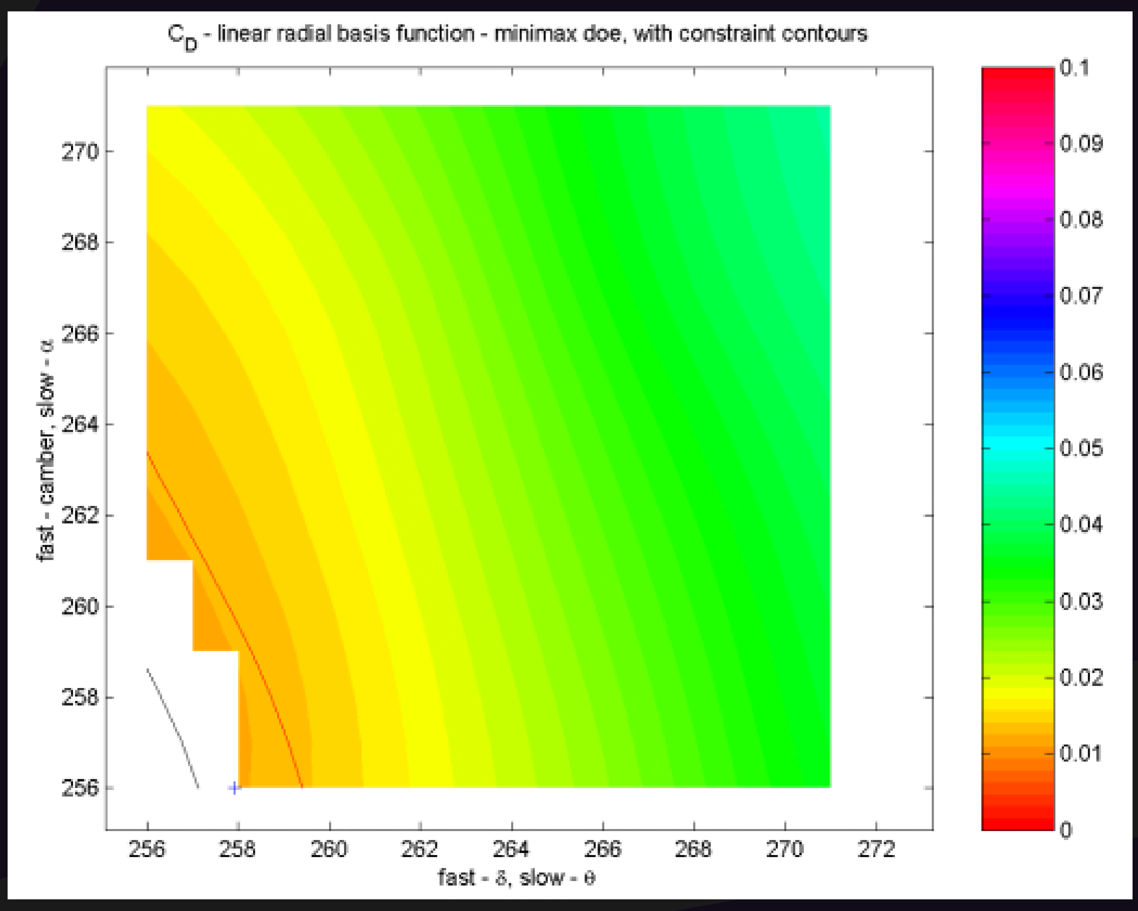
Minimise $C_{D,M=0.85}$

(With C_D being the drag coefficient and M the Mach Number) by varying the design variables: angle of attack (α) wing twist angle (θ) flap deflection angle (δ) and camber, such that straight and level flight must be achievable:
$C_{L,total} = C_{L,wing} \geq 0.1994$

where $C_{M\,l.e}$ is the pitching moment about the wing leading edge, *c* is the wing chord and *h* is the distance from the aerodynamic centre to the centre of gravity.

Here a response surface model (RSM) is used for each of the objective and constraints (alternatively constituents of these, C_L, C_D, $C_{M,l.e}$ could be modelled and the objective and constraints constructed from these). We determine how many evaluations can be afforded and exactly where in the design space these are going to be placed (we specify a Latin hypercube design of experiments, DoE). In our case one evaluation provides the objective and constraints, although this may not necessarily be the case. Here, 200 evaluations were performed across 9 computers in parallel in an overnight run. The next thing to determine is which RSM to use.

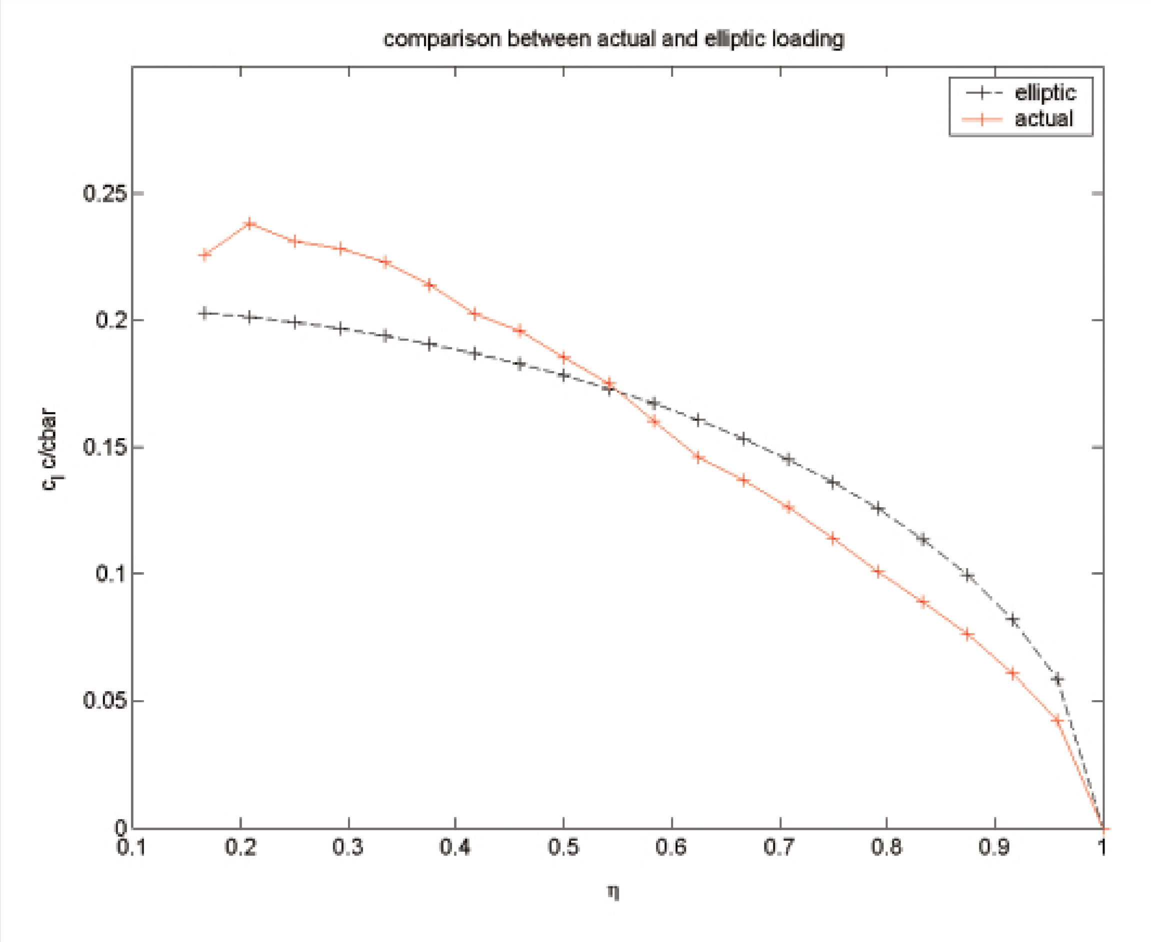




Here, a linear radial basis function (RBF) has been used, as there are a relatively large number of data points. In this problem there is an objective function, an inequality and an equality constraint and a separate response surface model (RSM) is required for each. A hierarchical axes technique (HAT) plot is constructed, in which the color of the tiles represents the objective function (Drag coefficient, C_D). The tile is only colored if the inequality constraint is satisfied. 3 contours of the trim constraint are shown, each being 0.1 apart, with the central contour satisfying the trim constraint. Only the fast variables, camber and flap deflection angle (δ) vary within one tile and the slow variables change from tile to tile.

The original DoE points are also shown, with the values of α and θ) being used to place the point on the nearest tile. Zooming in on a promising area enables a candidate design to be selected for evaluation.

The values of the four design variables at this point are: α=7.0, θ=7.0, δ=0.9, camber=0.0. The RSM at this point gives $C_D = 1.174 \times 10^{-2}$ with the actual value at this point (given by a new CFD calculation) as $C_D = 1.007 \times 10^{-2}$. The actual value of $C_L = 0.194$ and trim constraint = 1.004. The final wing loading distribution is as would be expected, similar to the ideal elliptic distribution, but with reduced lift outboard and increased lift inboard to compensate.



The next step in this work will be to increase the dimensionality of the problem to incorporate variables related to planform area.

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University of Southampton