Adaptive Length Encoding for Evolutionary Shape Optimisation

Tim Yates **Supervisor: Thorsten Schnier**
School of Computer Science, University of Birmingham

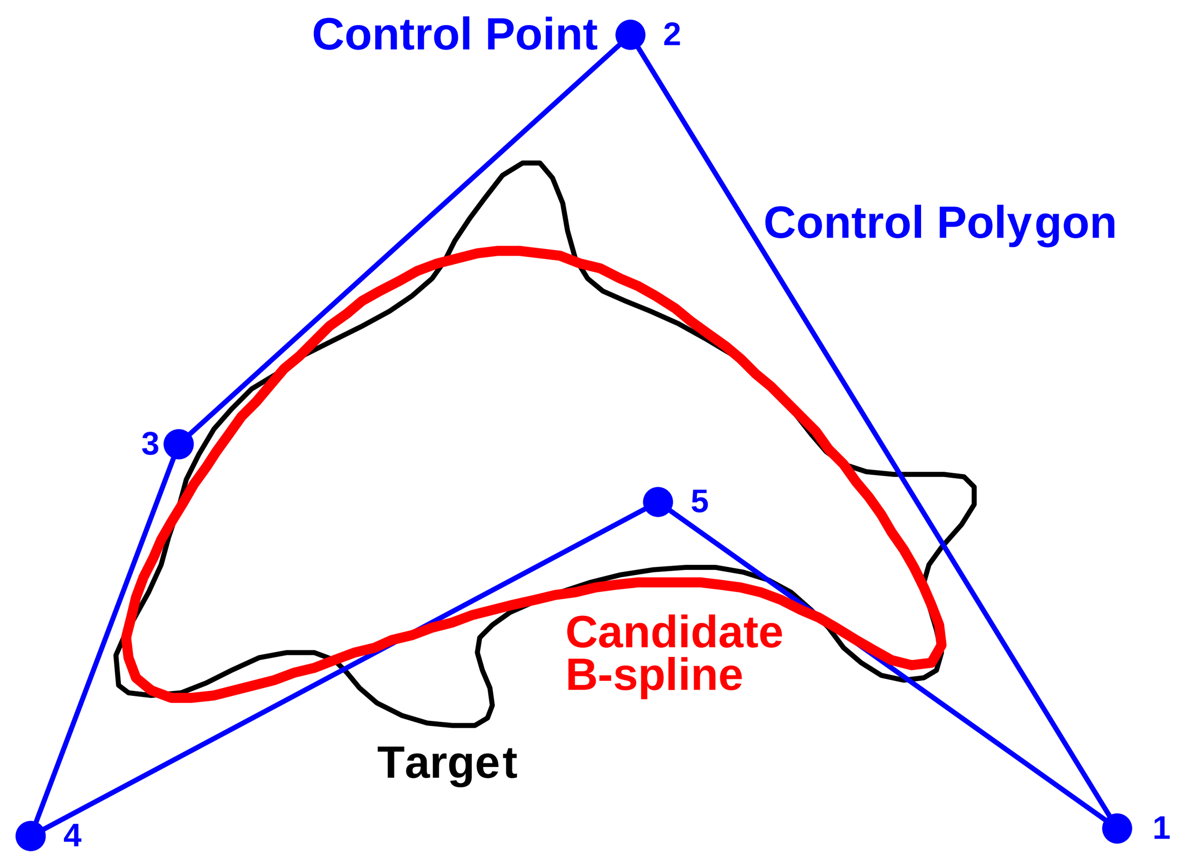
Introduction

Evolution strategies are increasingly being used to optimise aerodynamic designs, such as turbine blades. Design performance is evaluated by computational fluid dynamics simulations, which may take over an hour of processor time. As optimisation typically requires thousands of such evaluations, an efficient optimisation implementation is critical. To assess different implementations, the surrogate task of shape matching can be used.

Shape matching involves varying a candidate test shape until it matches a fixed target shape as closely as possible. The task is fundamentally the same as in aerodynamic design – to find the optimal shape – the main difference being that in shape matching a designer determines the best shape, rather than the physics of fluid flow.

Shape Encoding

A benchmark target [1] given by a set of 100 points in the shape of a dolphin was used throughout this study. Candidate test shapes are represented at the genotypic level by set of *control points* (CPs) and *knots* used to generate a smooth, cubic B-spline. The spline roughly follows the shape of the polygon formed by the CPs, and the knots determine how much influence each CP has on the spline. The phenotype is generated by sampling 100 uniformly separated points on the spline.

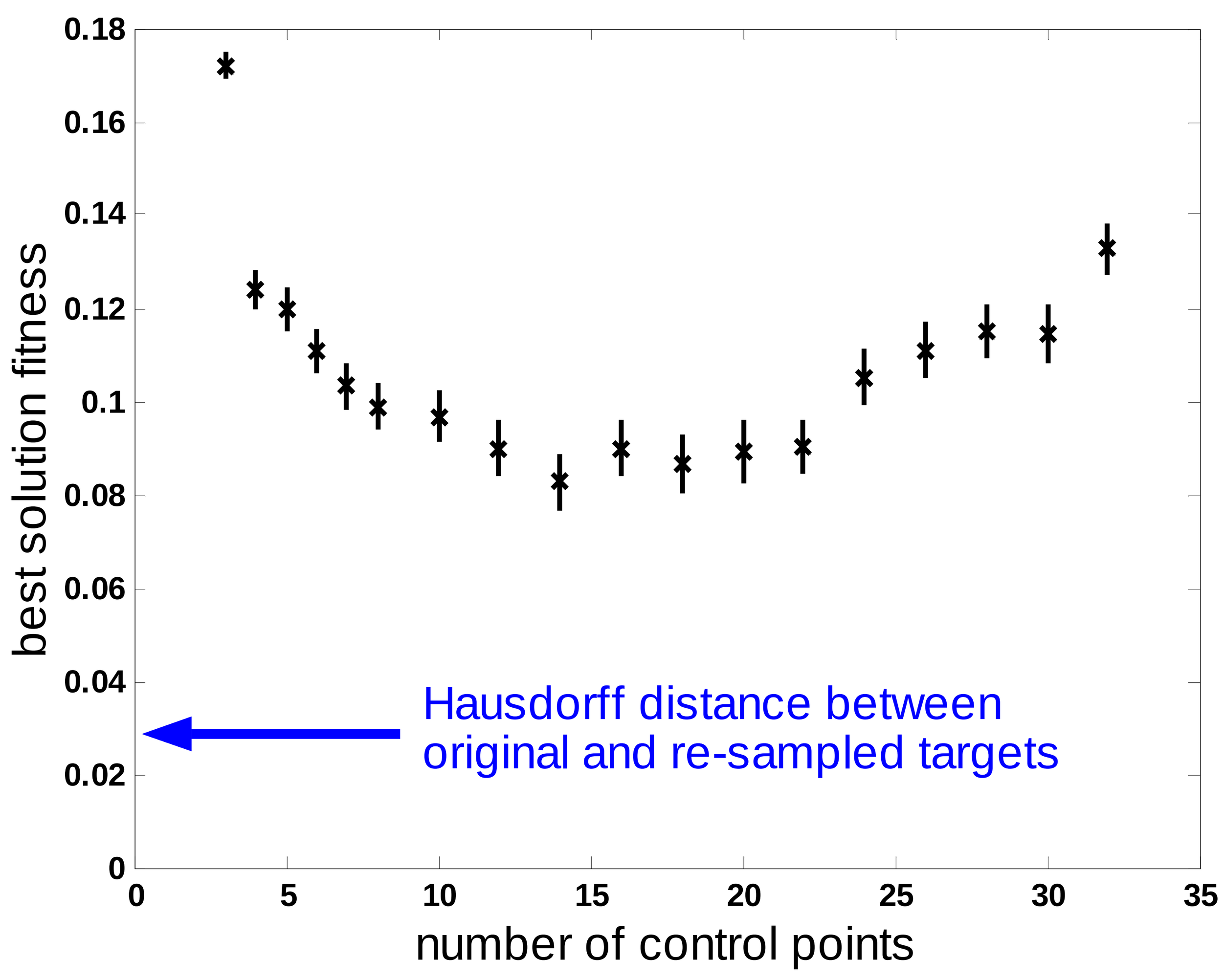


The fitness function to be minimised is a simple shape difference metric, the symmetric Hausdorff distance, which compares the two sets of 100 points.

To accelerate optimisation, adaptive length encoding [2] can be used; a 3-CP spline is initially optimised, then a fourth CP is added to the genotype, neutrally, before optimisation proceeds and the process is repeated. In the current study, the position and timing of new CP insertion has been investigated.

Baseline Data

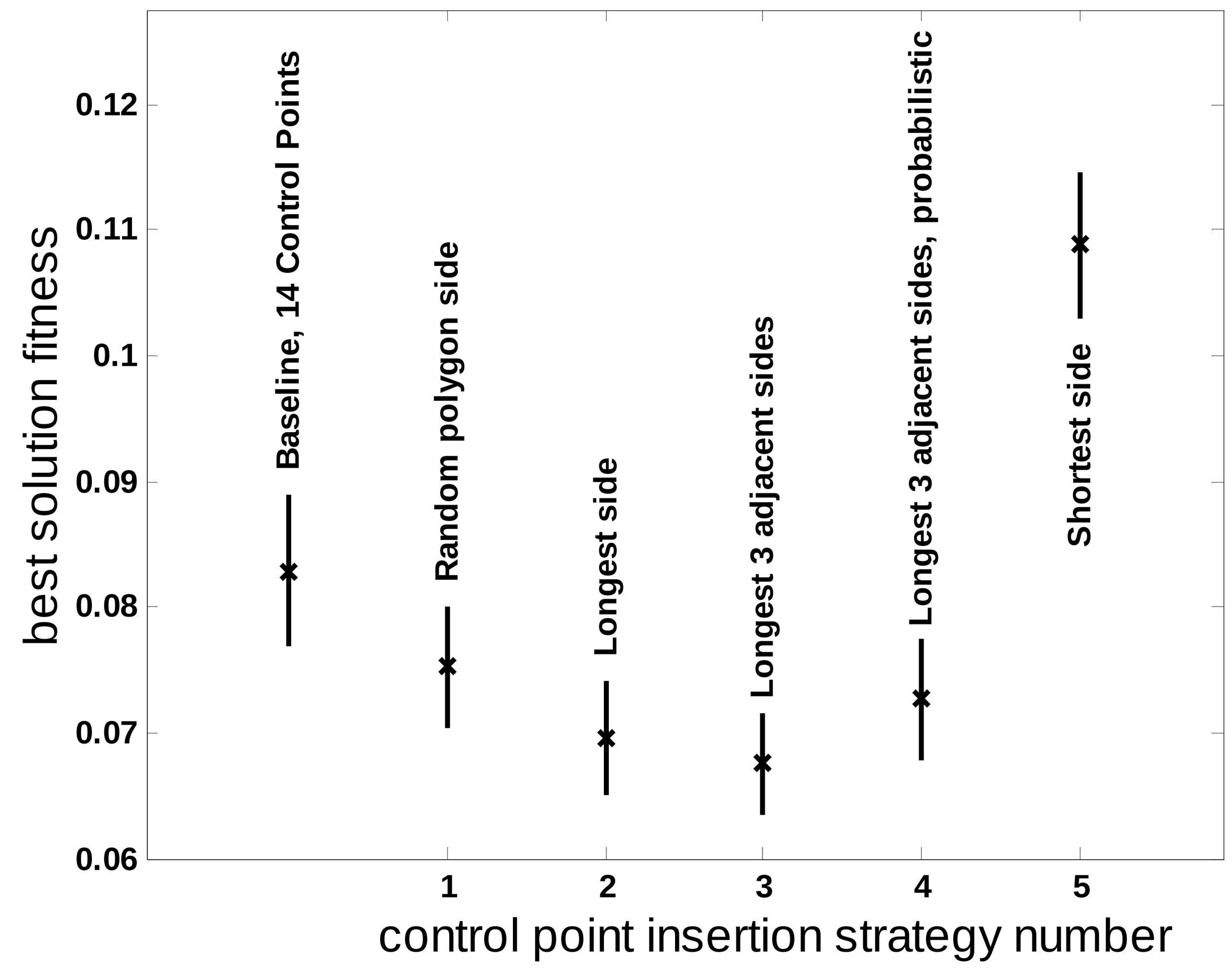
Before conducting the main experiments, baseline experiments were run using fixed length genotypes. All data shown are the mean and 95% confidence intervals from 25 runs of a (2,10)-ES with independent step size adaptation, as in [2]. Each run lasted for just 300 generations, as this is typical of the length of run used for aerodynamic design [3].



The best performance was achieved by a 14 CP genotype, giving a mean fitness of 0.083. Although the Hausdorff distance has a theoretical minimum of zero, resampling the points around the perimeter of the target using linear interpolation between the original points, and comparing with the original target gave a mean Hausdorff distance of 0.029. Thus even if a candidate spline passes through all the points of the target, we would still expect its fitness to be about this value.

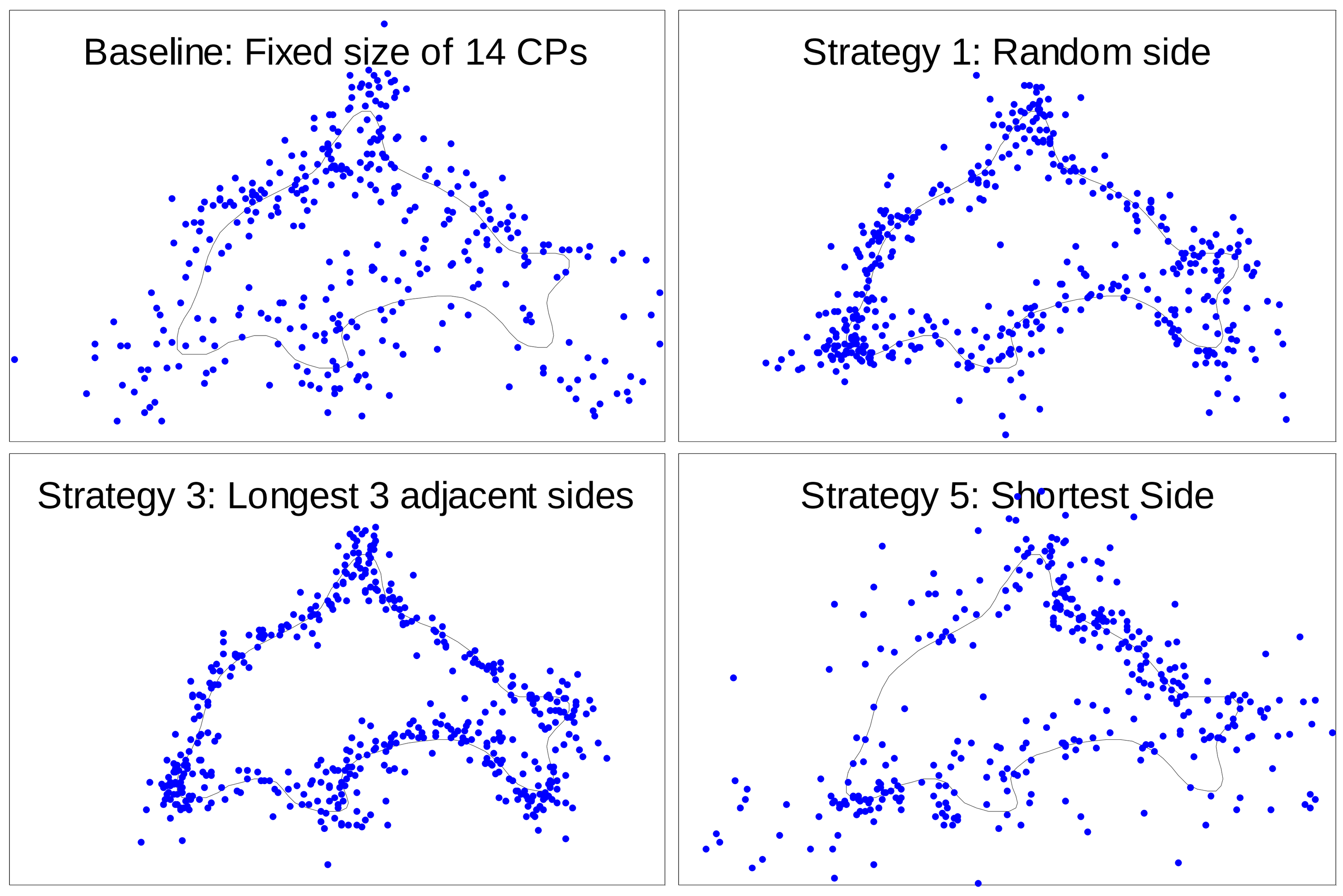
Adaptive Length Genotypes

In the first series of experiments, a new CP was inserted along one edge of the control polygon every 15 generations. Ten strategies to determine the best edge for insertion were tested, five of which are shown.

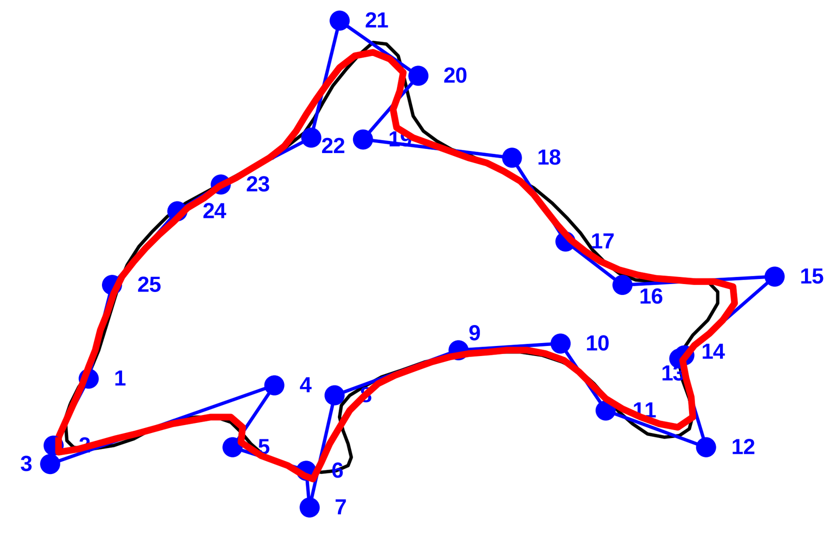


The greedy strategy (5) of inserting a point on the shortest side (where points have migrated together) gives worse performance than the baseline. Strategies that choose the longest polygon edge do better. The best strategy (3) finds the three adjacent sides with the greatest combined length, and inserts a new point on the central one. A variant of this strategy (4) uses the combined lengths as relative probabilities of choosing an edge, but this was not found to improve performance.

Scatter plots of the CPs from all 25 runs of different strategies show clear differences in the distribution of points around the target.



Further experiments have been run to determine when new CPs should be added. The best results have been found by inserting a new point when the number of mutations that produce worse solutions is equal to the number of CPs multiplied by 0.3. The best solution found using this approach is shown, it has a fitness of 0.043



Conclusions

- Variable length encoding can find better solutions than fixed length genotypes
- Strategies that aim to distribute control points uniformly perform better than both greedy and purely random approaches
- Further experiments need to be run using different target shapes

References

[1] The target is available at the online benchmark repository www.cs.bham.ac.uk/research/projects/ecb

[2] M Olhofer, Y Jin & B Sendhoff (2001). Adaptive encoding for aerodynamic shape optimization using Evolution Strategies. *Proceedings of the 2001 Congress on Evolutionary Computation* **1**: 576-583.

[3] Y Jin, M Olhofer & B Sendhoff (2001). Managing approximate models in evolutionary aerodynamic design optimization. *Proceedings of the 2001 Congress on Evolutionary Computation* **1**: 592-599.