Appendix E

Genetic algorithm shape optimisation of radiant heaters

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Abstract

The shape of radiant heaters can influence significantly the radiation distribution and therefore the effectiveness of heating processes. I will present an automated shape optimisation technique for tubular radiant heaters. A Genetic Algorithm was developed that optimises parameters describing the heater shape with respect to a user-specified radiation distribution over a work-piece. Three sample cases are presented that show the developed GA to be successful.

Genetic Algorithm Shape Optimisation of Radiant Heaters

Bryan Shaughnessy

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Background

- Present previous research on shape optimisation of radiant heaters
- Is there an opportunity to include this or a similar approach in a thermal analysis tool?

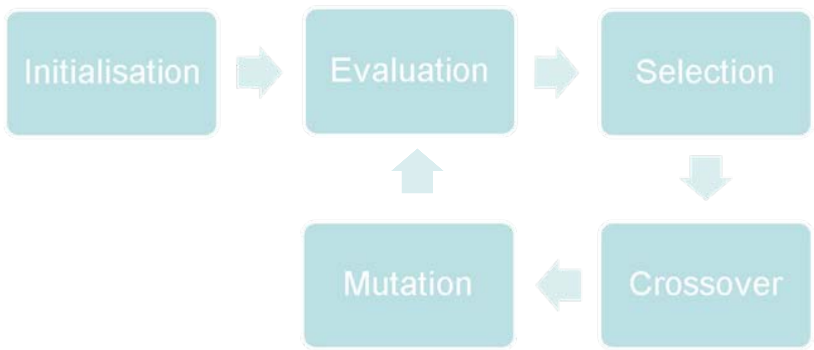
Applications

- Fluids loop routing
- Heater placement
- Thermal shield geometry

Genetic Algorithms (GAs)

- Evolve a population of candidate solutions
- Candidate solutions encoded as chromosomes
- Mathematical operations on chromosomes simulate evolution
  - Based on probability functions
  - GA parameters/probabilities may require tuning

Genetic Algorithms



Brief Definitions

- Evaluation
  - Decode all chromosomes, solve, and rank
- Selection
  - Chromosomes selected for new population.
- Crossover
  - Promote exchange of information to produce ‘offspring’ solutions
- Mutation
  - Introduce variability into the population

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Shape Representation

- Not practical to represent shapes in terms of coordinates
- B-Spline representation used
  - Complex shapes defined using small number of control points
  - Chromosome is the vector of control points: $[x_1, y_1, x_2, y_2, \ldots.. x_n, y_n]$
- Constraints (end-points, range of ordinates)

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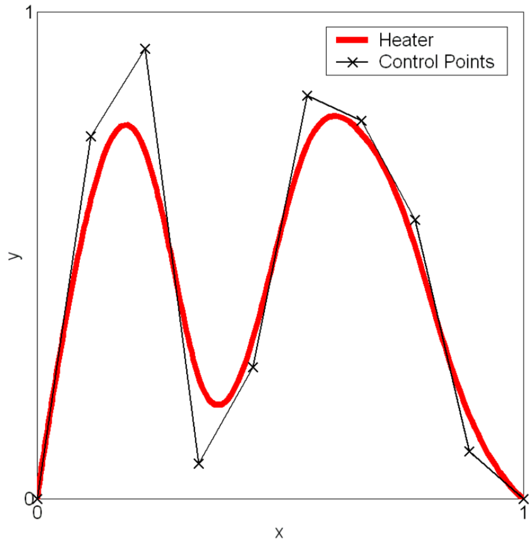
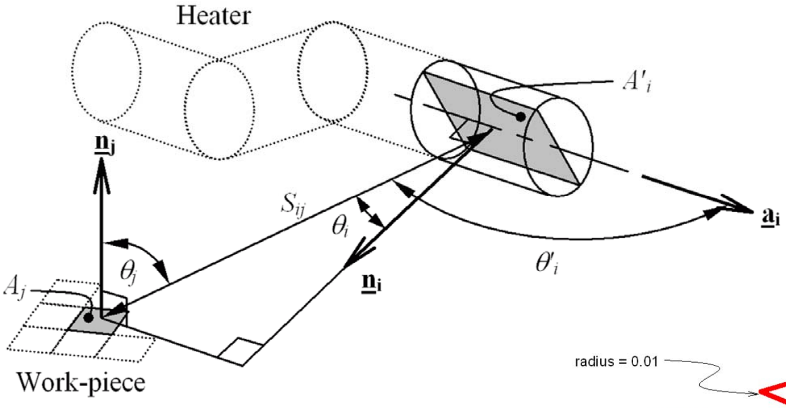
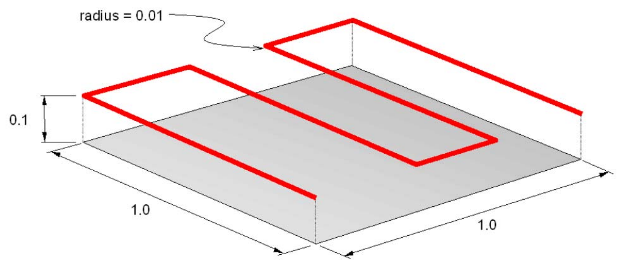
Geometry defined by B-Spline



Radiative Model





Performance Measure

- Compare view-factor distribution with a user-defined distribution
- Distributions normalised and average difference calculated
- Average difference → 0 for better heaters
- Population selection
  - Random selection using a cumulative density function
  - 'Elitist' approach

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Initialisation of first Population

- Random initialisation of control points could give shapes with self-intersections
- To avoid this:
  - x-ordinates distributed evenly
  - y-ordinates allocated randomly

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Crossover

- Select pairs of chromosomes according to probability P_c
- Swap the coordinates of each pair at a random point
- Example:

Before Crossover

A	B	C	D	E	F
1	2	3	4	5	6

After Crossover

A	B	3	4	5	6
1	2	C	D	E	F

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Mutation

- Ordinates selected according to probability P_m
- Selected ordinates modified by a random amount within a maximum allowable deviation
- Important because generates new control-points
  - With the floating-point representation, crossover does not generate new control-points

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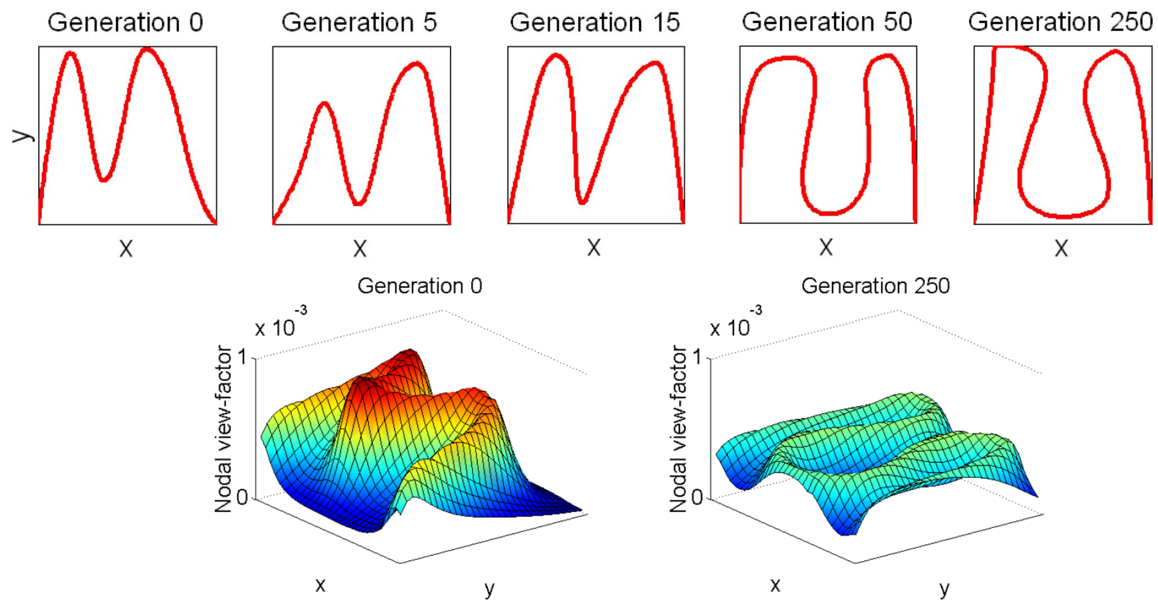
GA Simulation – Uniform



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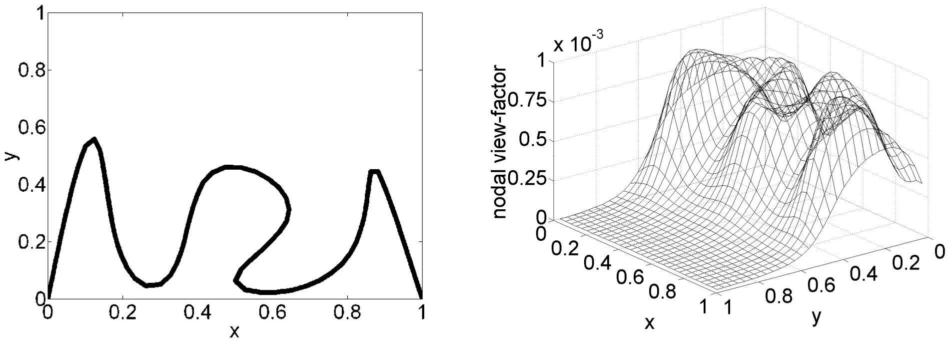
GA Simulation – Step



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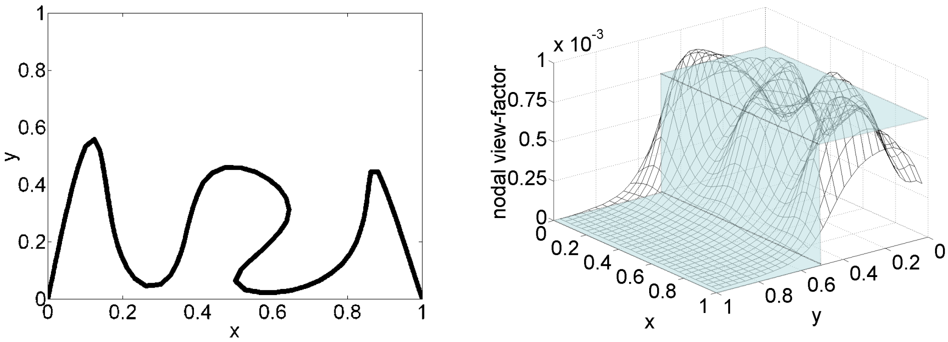
GA Simulation – Step



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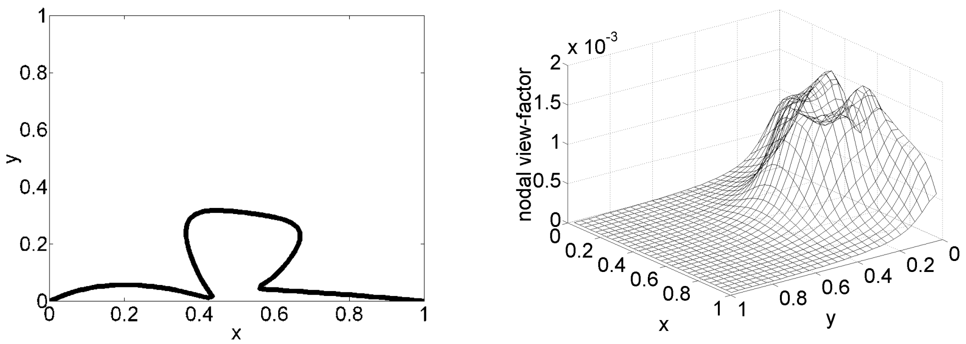
GA Simulation – Triangular Step



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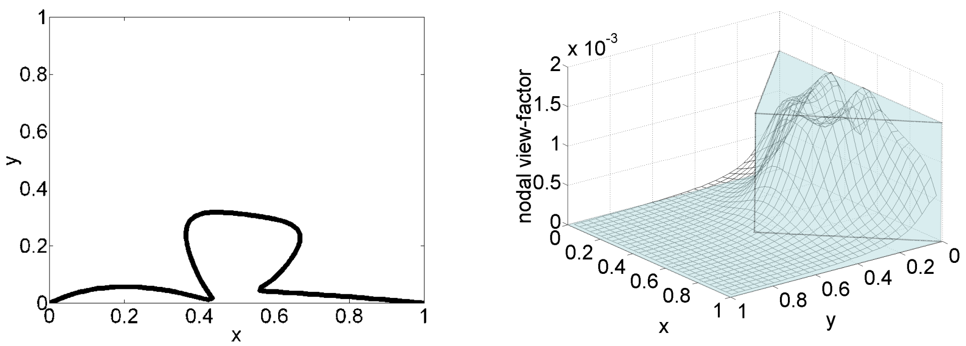
GA Simulation – Triangular Step



Conclusions

- Effective method of optimising radiant heater shapes
- Wider application?
  - Requires fast solvers
  - Requires effective methods of constraining/avoiding unrealistic geometry

Reference

- B. M. Shaughnessy and M. Newborough. "Genetic Algorithm Shape Optimisation of Radiant Heaters for Thermal Processing Applications". International Symposium on Advances in Computational Heat Transfer, 2001