Memetic Algorithms in the Solution of Inverse Heat Conduction Problems

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Memetic Algorithms

- Combination of two types of algorithms
  - Population based global search
  - Local search
- Have been used to solve optimization problems
- Optimization of real values functions is relatively slow using EA
- Perform quicker local search using a hill-climbing algorithm

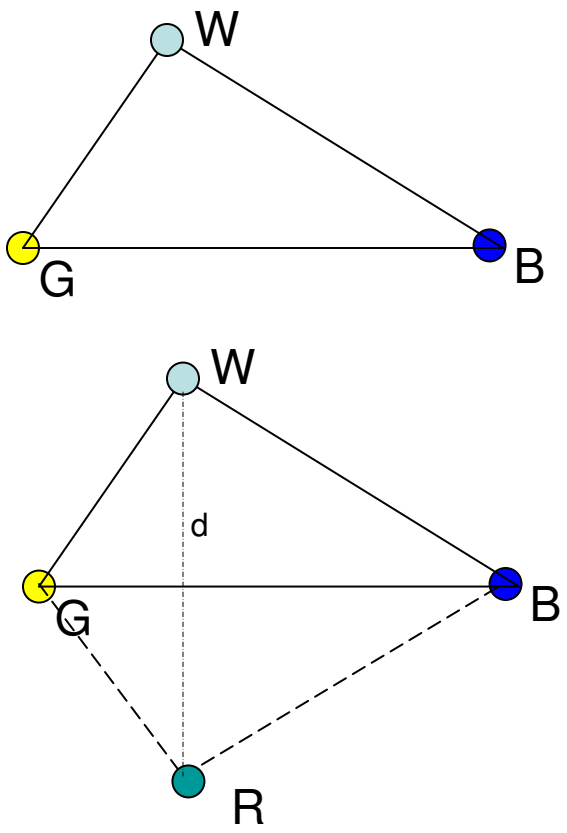
Memetic Algorithm

- Evolutionary algorithm for global search
- Nelder-Mead simplex method for local search
- Advantages of simplex methods
  - No computation of derivatives
  - Faster than an evolutionary algorithm on real numbers

Nelder-Mead Simplex Method

- Direct search method
  - Does not need derivative information
- Simplex is a polyhedron consisting of n+1 points (n-dimensions)
  - Triangle in a 2 dimensional plane
  - One of the points is taken as the origin
  - Vectors are constructed using other points
  - *Reflection, Expansion, Shrinking* are performed on the simplex to move towards the optimal solution

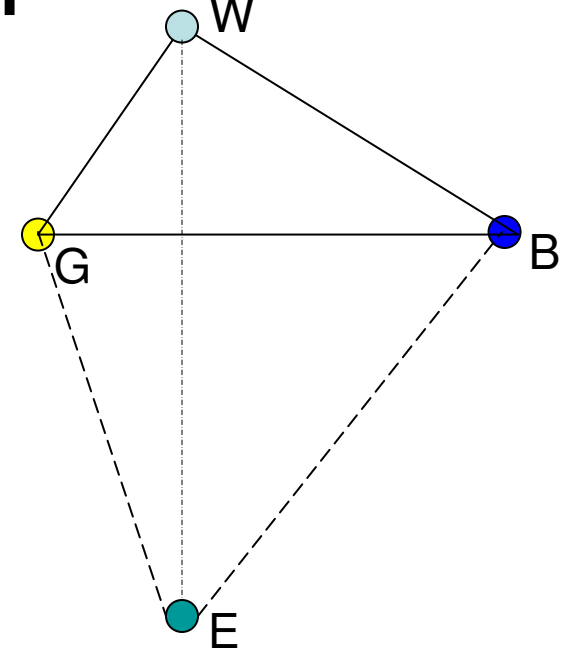
Nelder-Mead Simplex Method

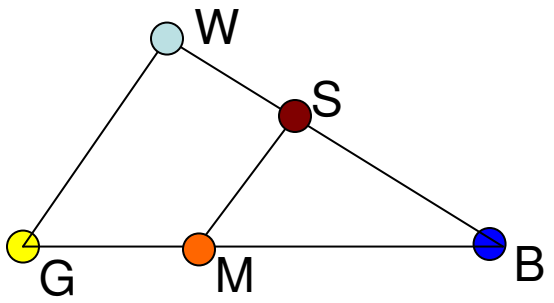


- Example in two dimensions (minimization)
  - Three points
  - Find the Best (B), Good (G) and Worst (W) points
  - *Reflect* triangle about side BG

Nelder-Mead Simplex Method

- If R < W => correct direction, apply *Expansion*
- If R > W, apply *Shrinking* transformation
- Additional checks for R = W





Memetic algorithm

- Overview of algorithm

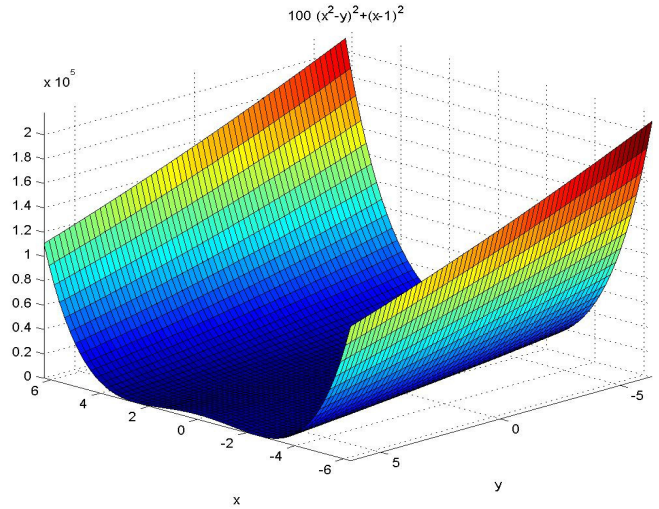
Step 1: Start evolutionary algorithm by initializing random solutions
Step 2: Evaluate candidate solutions (mating events)
Step 3: If number of mating events (N_m) is a certain number, send best member to NM algorithm
Step 3(a): NM algorithm explores the local search space to find best possible solution.
Step 3(b): Store solution from NM method.
Step 4: Continue to Step 2, until convergence of evolutionary process

Test Functions

- Test Function 1

$$f = 100(x^2 - y)^2 + (x-1)^2$$

Evolutionary Algorithm	Memetic Algorithm
783	350



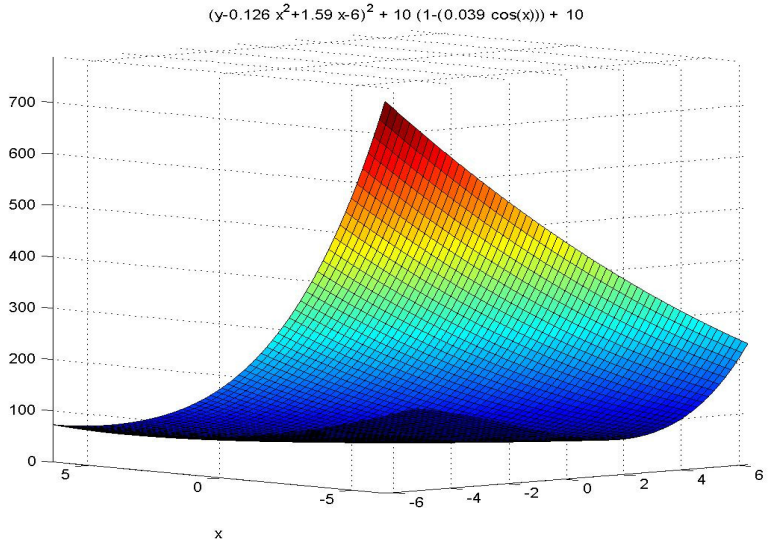
Test Functions

- Test Function 2

$$f = (y - (5/(4\Pi^2))x^2 + (5/\Pi)x - 6)^2 + 10(1 - (1/8\Pi))\cos(x) + 10$$

- 3 global maxima

Evolutionary Algorithm	Memetic Algorithm
954	412



Evolutionary Algorithm

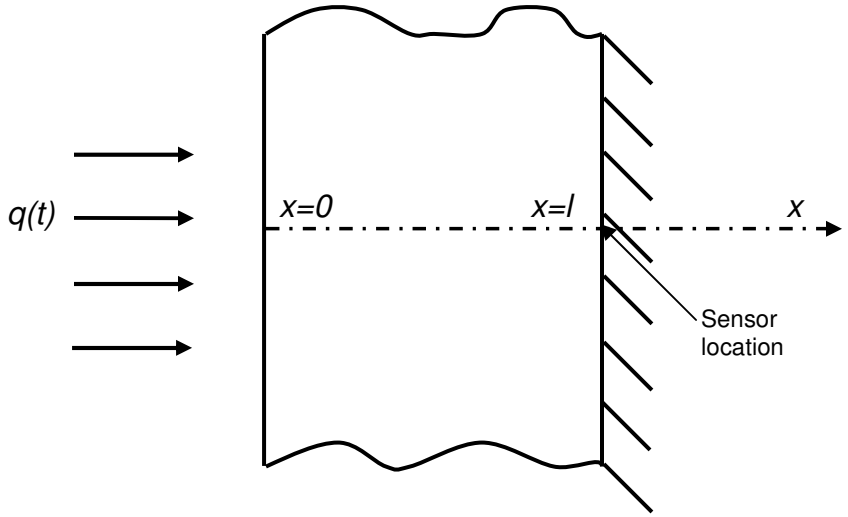
- Chromosome

q_0	q_1	q_2	q_3				q_{n-3}	q_{n-2}	q_{n-1}

- Mutation
  - Perturb value at a random location
- Crossover
  - Two point crossover

Inverse Heat Conduction Problem

- Estimating transient heat flux from temperature response



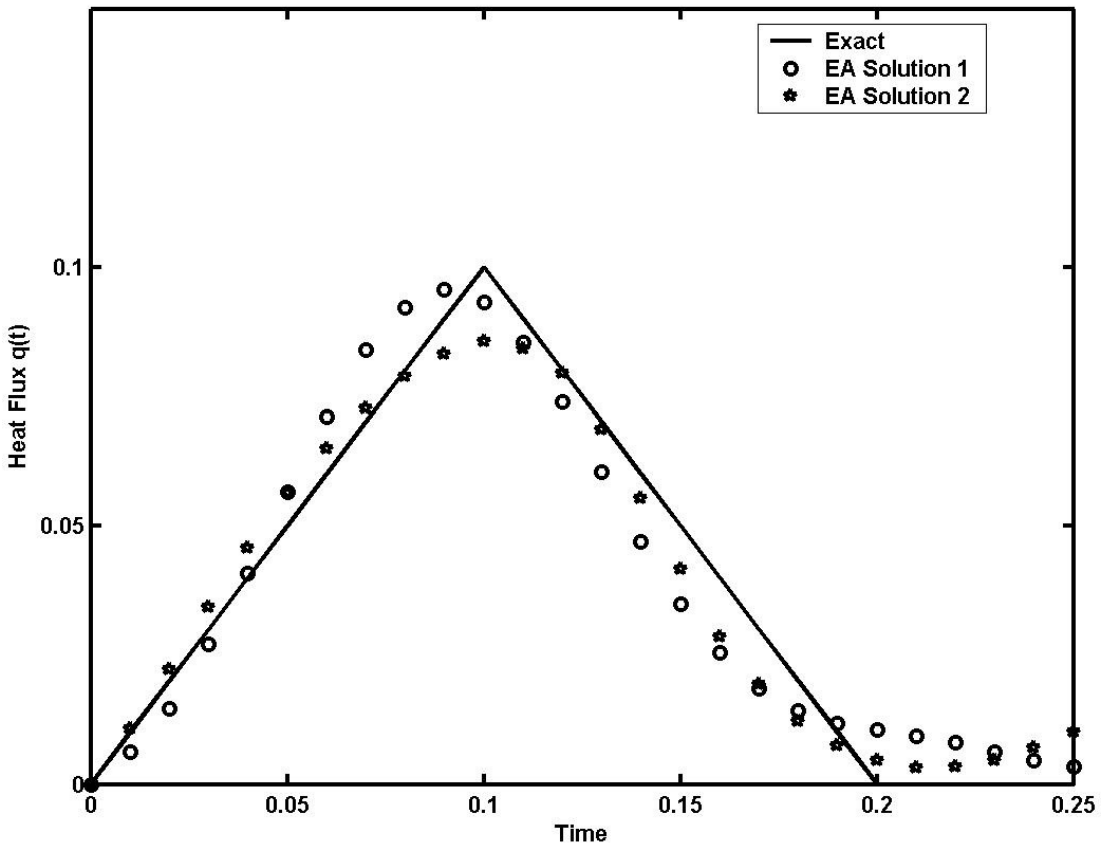
- Fitness function

$$f = \sum_{j=0}^{j=t_f} (T_j^{cand} - T_j^{spec})^2 + \lambda \sum_{j=0}^{j=t_f} (q_{i+1}^{spec} - q_i^{spec})^2$$

- Converted to a maximization problem using

$$f_{max} = \frac{1}{(f + 10^{-2})}$$

Solution from memetic algorithm



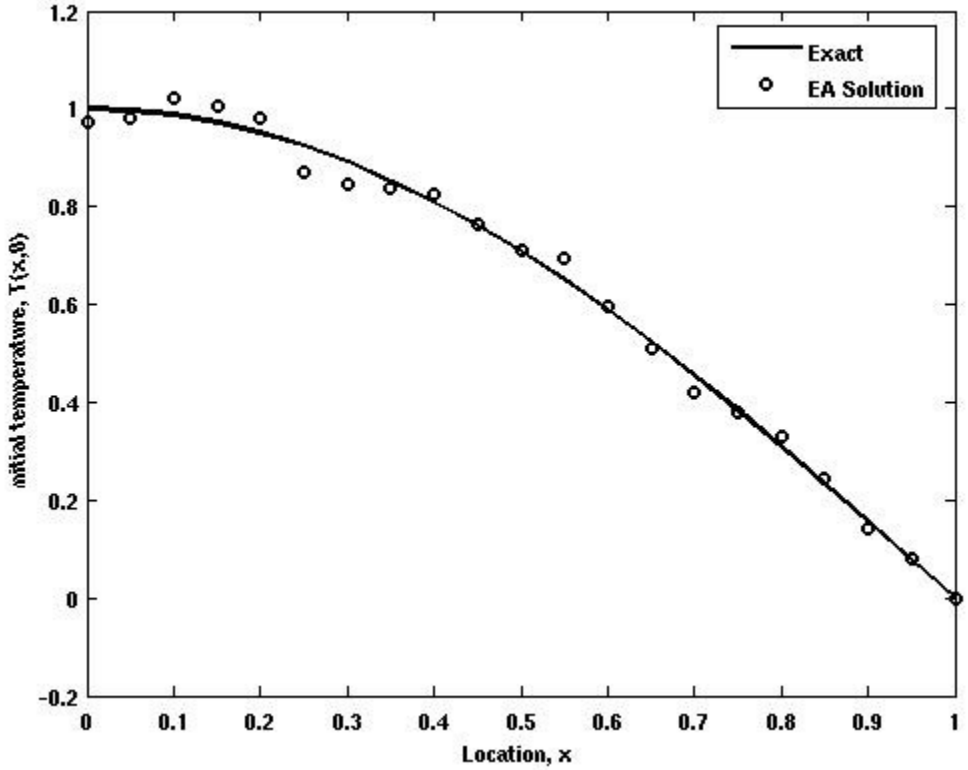
Backward Heat Conduction Problem

- Test case 1
- Estimation of initial temperature
- Test problem
  - Same as previous IHCP
  - Initial condition

$$g(x) = \cos(\frac{\pi \cdot x}{2})$$

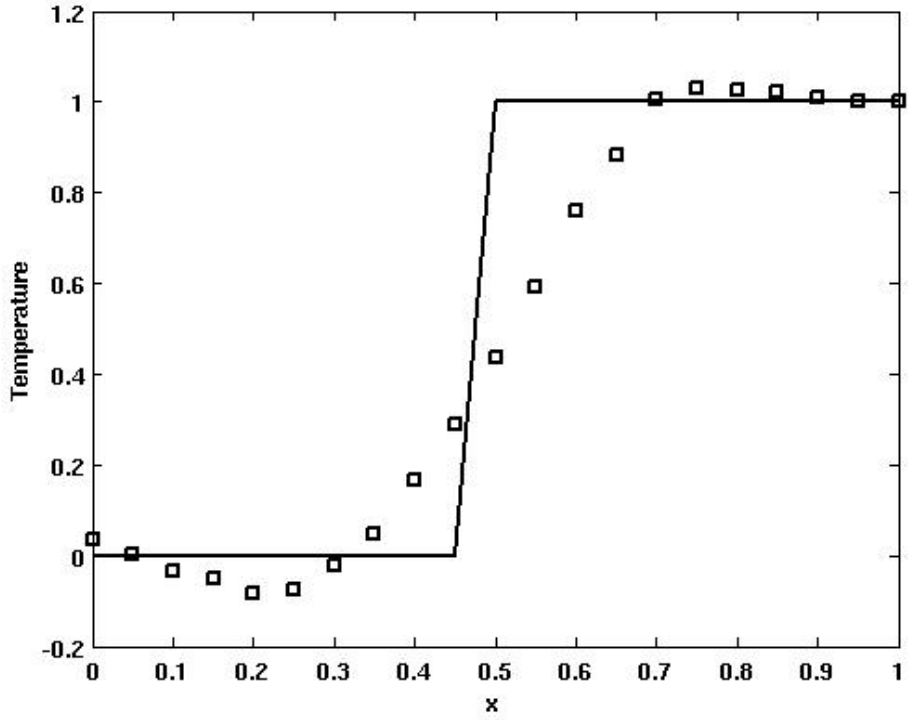
- Solved as an optimization problem using the memetic algorithm

Backward Heat Conduction Problem



Backward Heat Conduction Problem

- Test case 2
  - Discontinuous initial temperature profile



Time to Solution

- IHCP
- BHCP 1
- BHCP 2

EA	MA
2050	720
1845	375
2262	719

Conclusions and Future Work

- Savings in run time using the memetic algorithm
- Increased accuracy of solutions
- Tested with several multi-modal functions
- Apply the memetic algorithm to other inverse problems