Australian National University

Bacterial Evolutionary Algorithms (BAEs) and Memetic Algorithms

Tom Gedeon

Research School of Computer Science

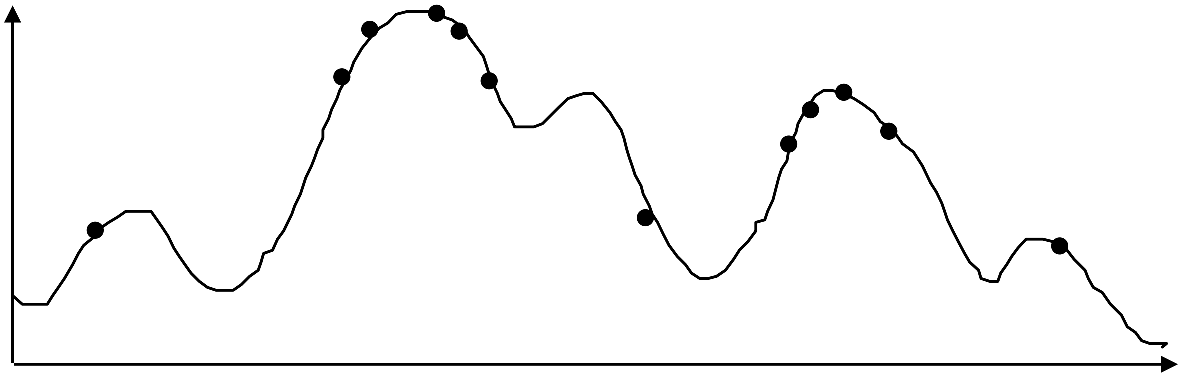
Australian National University

tom@cs.anu.edu.au

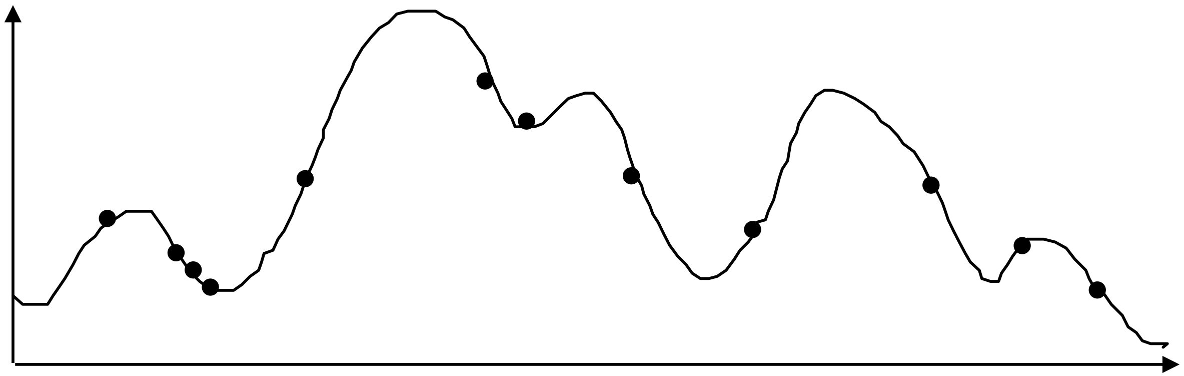
Based on slides by János Botzheim

Human Centred Computing

Evolution of the population



Distribution of Individuals in Generation 0



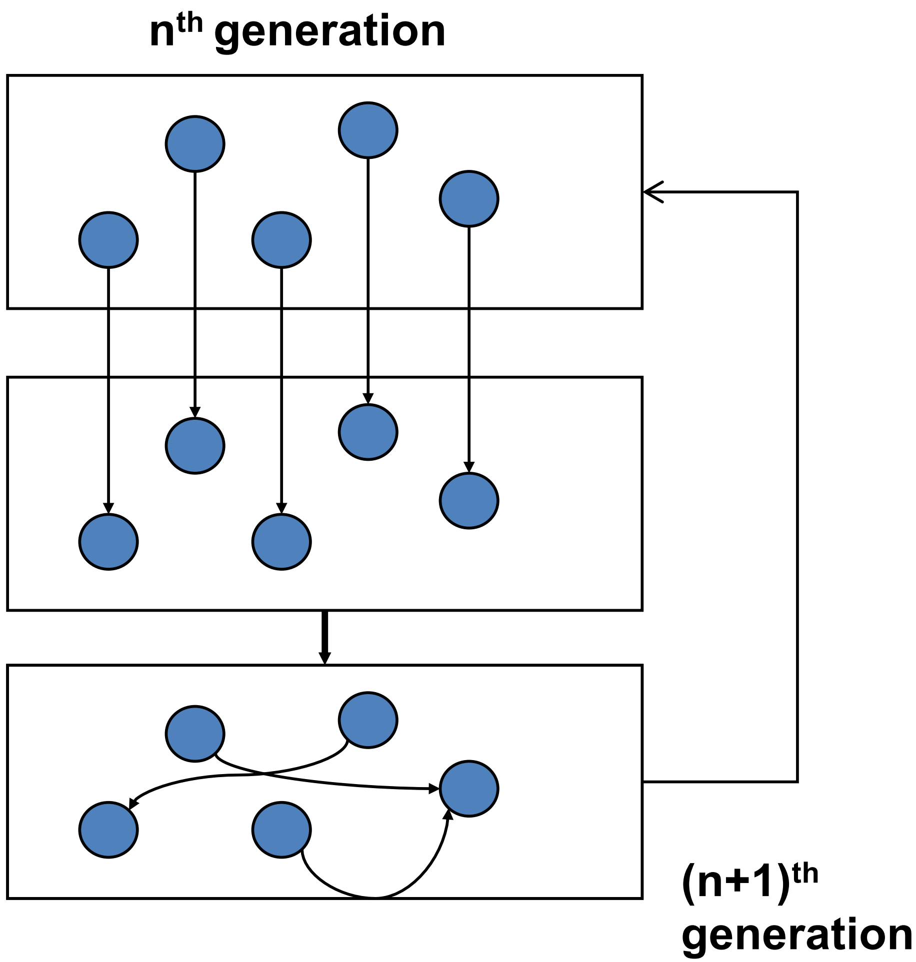
Distribution of Individuals in Generation N

Bacterial evolutionary algorithms

- Nature inspired optimisation techniques
- Based on the process of microbial evolution
- Applicable for complex optimisation problems
- Each individual: one solution of the problem
- Intelligent search strategy to find *sufficiently good* solution (quasi optimum)
- Fast convergence (conditionally)

The algorithm

- Generating the initial population randomly
- Bacterial mutation is applied for each bacterium
- Gene transfer is applied in the population
- If a stopping condition is fullfilled then the algorithm stops, otherwise it continues with the bacterial mutation step



Bacterial mutation

Part 1 Part i Part n

One part is randomly chosen

↓

The i^{th} part is mutated in the N_{clones} clones, but not in the original bacterium (bacterial mutation)

↓

The best bacterium transfers its i^{th} part to the other bacteria

↓

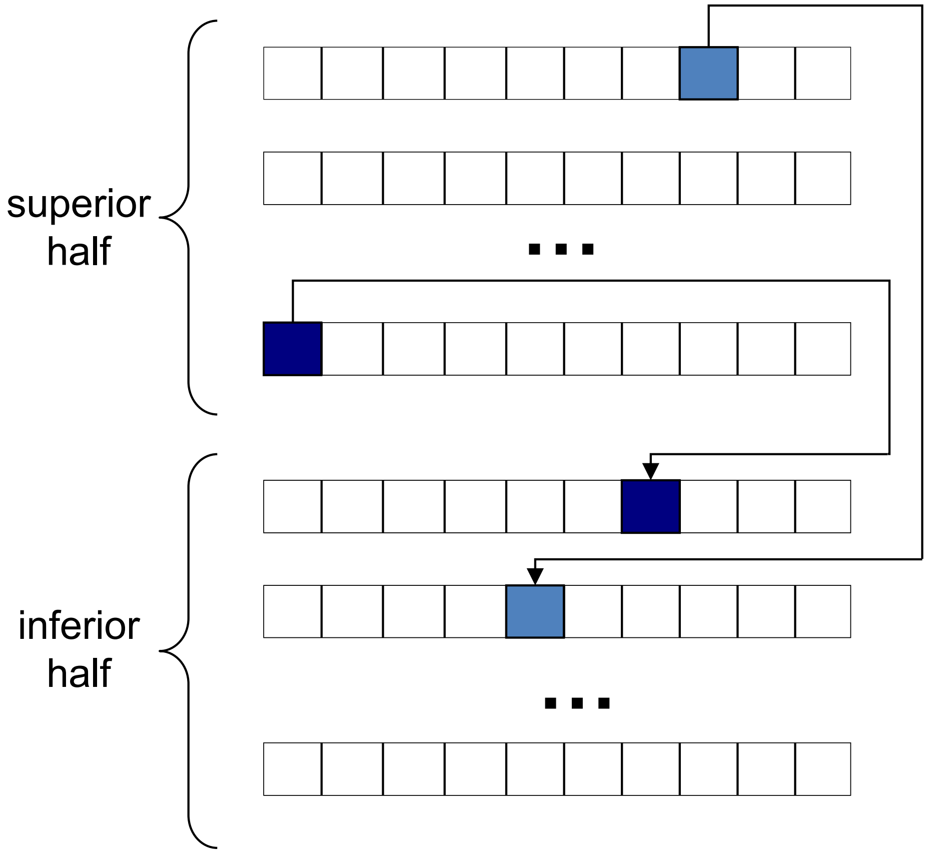
Repeat until all the parts are mutated and tested

N_{clones} clones

Gene transfer

1. The population is divided into two halves
2. One bacterium is randomly chosen from the superior half (source bacterium) and another from the inferior half (destination bacterium)
3. A part from the source bacterium is chosen and this part can overwrite a part of the destination bacterium

This cycle is repeated for N_{inf} times (number of “infections”)



Parameters

- N_{gen}: number of generations
- N_{ind}: number of individuals
- N_{clones}: number of clones in the bacterial mutation
- N_{inf}: number of infections in the gene transfer

Differences between GA and BEA

- GA based on the evolution process of mammals, while BEA based on the evolution process of bacteria
- GA uses crossover, BEA uses gene transfer for the information flow in the population
- Bacterial mutation is more effective than mutation in GA
- There is no selection in BEA, but there is multiplication by fission (cloning method)

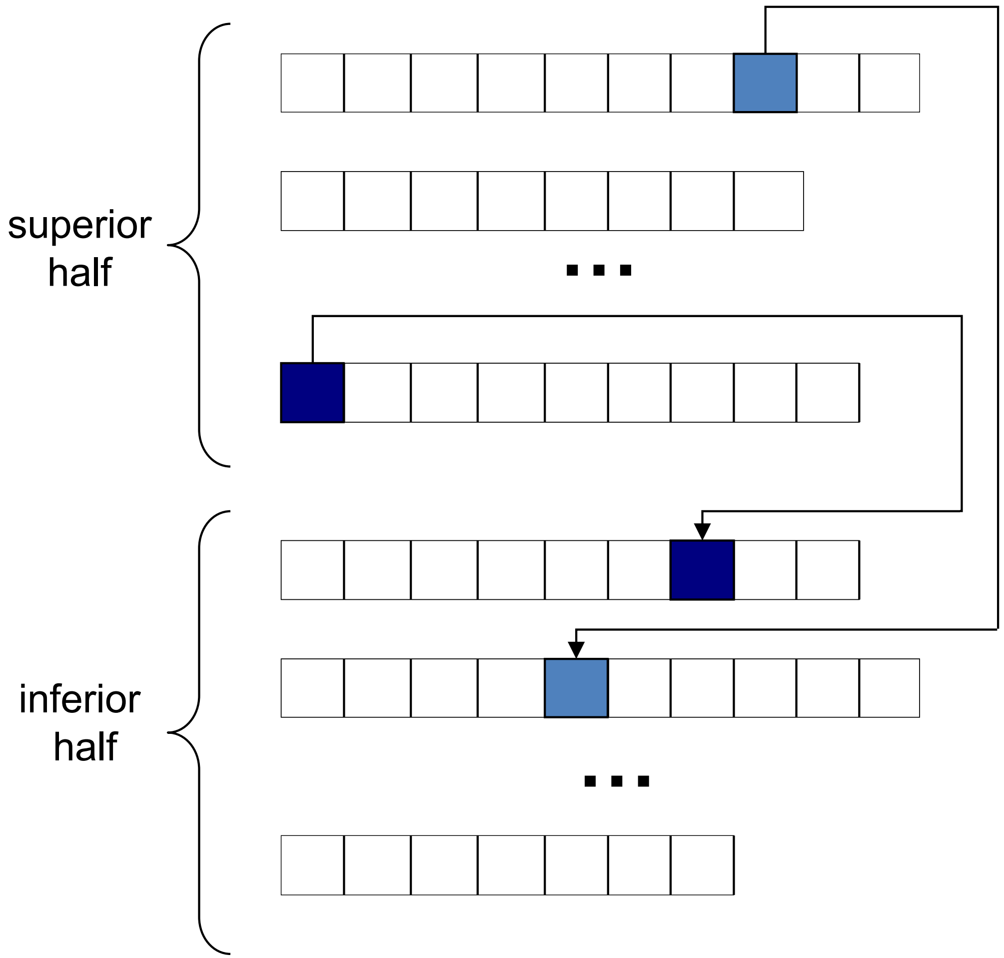
Improved bacterial mutation

- The number of clones (N_{clones}) and the length of the segment (l_{BM}) are parameters of the bacterial mutation
- The mutation may change not only the content, but also the length
- The length of the new elements is chosen randomly as $l_{BM} \pm l^*_{BM}$, where l^*_{BM} is a parameter specifying the maximal change of length in a single mutation
- When changing a segment of a bacterium, we must observe that the new segment will be unique within the selected bacterium

Improved gene transfer

1. The population is divided into two halves according to their evaluation results
2. One bacterium is randomly chosen from the superior half (source bacterium) and another from the inferior half (destination bacterium)
3. A segment from the source bacterium is randomly chosen and this segment will overwrite a random segment of the destination bacterium if the source segment is not already in the destination bacterium

This cycle is repeated for N_{inf} times (number of "infections")



Improved gene transfer (cont.)

- The number of infections (N_{inf}) and the length of the source segment (l_{GT}) are parameters of the gene transfer
- The gene transfer may not only change the content, but also the length of the destination bacterium
- The length of the new segment in the destination bacterium is chosen randomly as $l_{GT} \pm l^*_{GT}$, where l^*_{GT} is a parameter specifying the maximal change of length in the destination bacterium

Parameters

- N_{gen}: number of generations
- N_{ind}: number of individuals
- N_{clones}: number of clones in the bacterial mutation
- N_{inf}: number of infections in the gene transfer
- *MutationLength*: the length of the mutated segment (l_{BM})
- *ModifiedMutationLength*: the maximal allowed difference between the lengths before and after the mutation in one segment (l^*_{BM})
- *GeneTransferLength*: the length of the source segment (l_{GT})
- *ModifiedGeneTransferLength*: the length of the change in the destination bacterium (l^*_{GT})
- *MAXLEN*: maximum allowed length of a bacterium ($\cdot$ n)
- β: trade-off parameter between accuracy and complexity

Theories of Evolution

- Jean-Baptiste Lamarck
  - *Theory of Inheritance of Acquired Characteristics*
  - if an organism changes during life in order to adapt to its environment, those changes are passed on to its offspring
- Charles Darwin
  - the desires of animals have nothing to do with how they evolve
  - changes in an organism during its life do not affect the evolution of the species
- James M. Baldwin
  - a new factor in evolution
  - acquired characteristics could be indirectly inherited

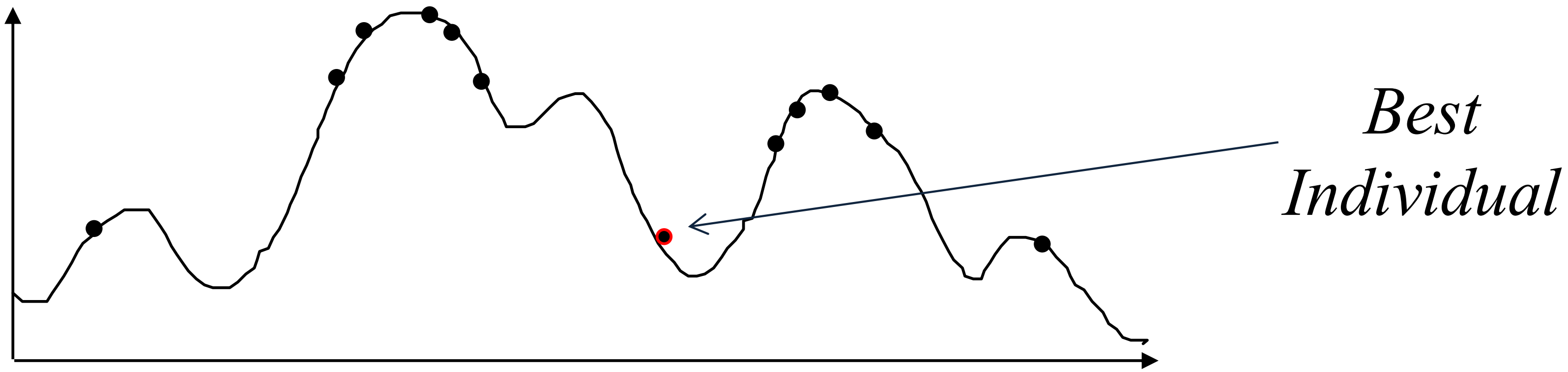
Memetic algorithms

- A combination of evolutionary algorithms with local search operators that work within the EA loop are called “Memetic algorithms”
- Memetic Algorithms were introduced by Moscato *et*. *al*. (~1989)
- Terminology:
  - meme = unit of cultural transmission (the ”genes” of cultural evolution)
  - ”mimema”, imitate

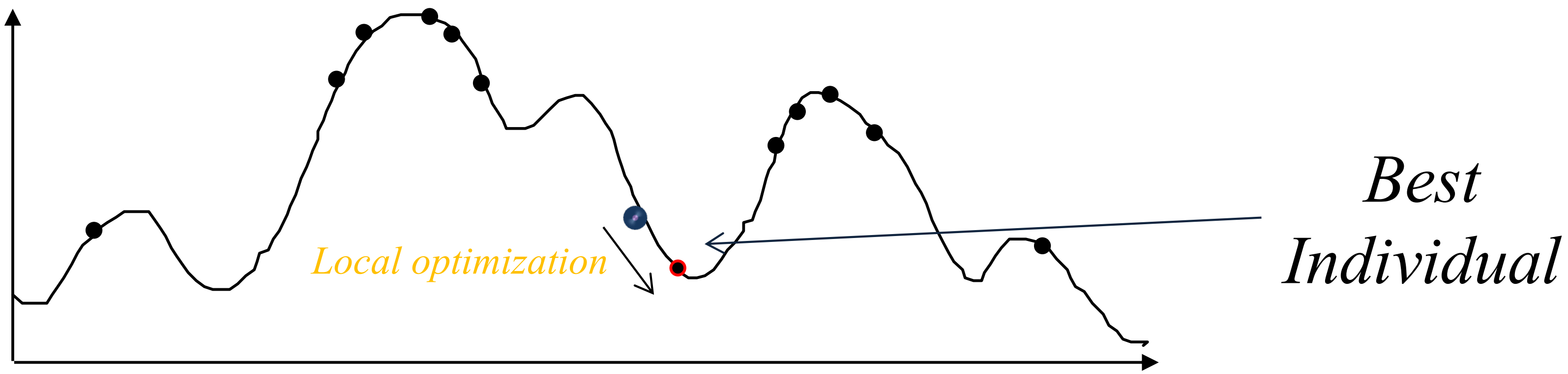
Why hibridize?

- Evolutionary Algorithms
  - Explore large, rough search spaces
  - Difficulties with fine-tuning
- Local search techniques
  - Optimise/converge fast
  - Get stuck in local optima
- Disadvantages:
  - There are costs of the learning
  - The learning is not always good

Memetic Optimization



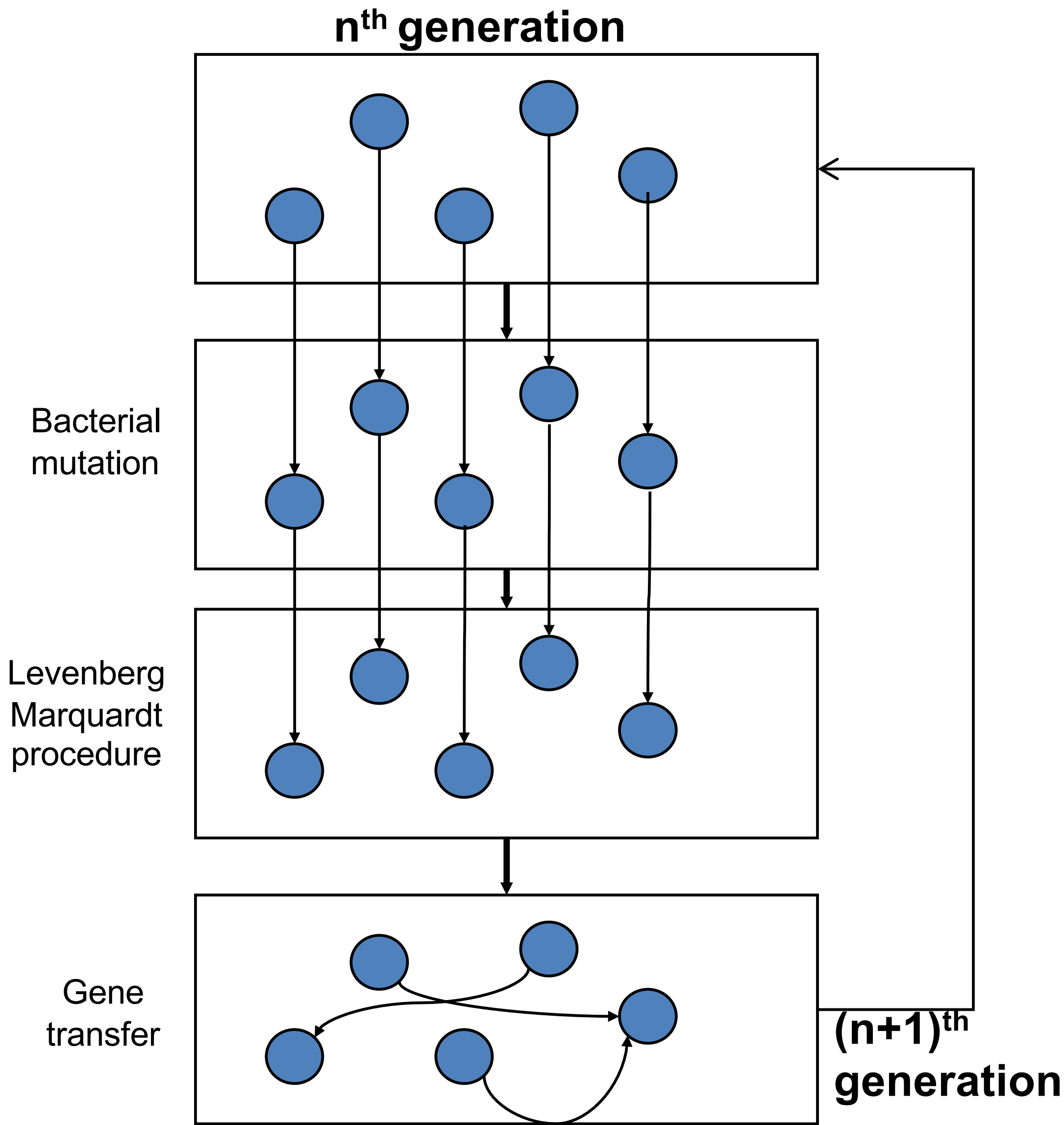
Evolutionary Optimization



Distribution of Individuals in Generation N

Bacterial memetic algorithm

- Generating the initial population randomly
- Bacterial mutation is applied for each bacterium
- Levenberg-Marquardt method is applied for each bacterium
- Gene transfer is applied in the population
- If a stopping condition is fullfilled then the algorithm stops, otherwise it continues with the bacterial mutation step



The Levenberg-Marquardt method

- Second-order gradient-based training method
- Belongs to the group of ‘trust-region’ or ‘restricted-step’ type methods
  - Attempts to define a neighborhood where the quadratic function model agrees with the actual function in some sense. The parameter α controls the radius of neighborhood
- Local search optimizer
- It can be used to improve asevolutionary algorithm, which may find the global optimum with higher precision in this way
- The evolutionary and local search hybrid methods are usually referred to as memetic algorithms
- A new memetic method is: bacterial memetic algorithm

Parameters of the algorithm

- N_{gen}: number of generations
- N_{ind}: number of individuals
- N_{clones}: number of clones in the bacterial mutation
- N_{inf}: number of infections in the gene transfer
- N_{iter}: number of iterations in the LM step
- α: regularization parameter in the LM step

Conclusions

- Increasing the number of generations and the number of individuals also increases the performance of the algorithm (however, it causes additional computational effort)
- Optimal clone number? – local minima problem
- Gene transfer: enable interaction between the bacteria
- Faster convergence
- The gene transfer operator can be realized easier than the crossover operator in genetic algorithms

Conclusions

- The bacterial memetic algorithm gives better results than the bacterial evolutionary algorithm
  - In terms of the optimization criterion
  - In the sense of other generalized criteria
- By the bacterial operators the local minima can be avoided
- Using the Levenberg-Marquardt method the locally best fitting can be found
- Thus, the global minimum can be found with larger accuracy