Advanced Techniques for the Visualization of Evolutionary Algorithms

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Overview

- Motivation
- Standard set of visualization techniques
- Advanced method for multidimensional data
- Summary and Outlook

Introduction

Evolutionary Algorithms

- work algorithmically simple
- produce vast amount of data

non-trivial

- extract useful information to provide insight into
  - → state of the population,
  - → progress of the Evolutionary Algorithm

→ presentation of

- → set of standard methods for different data types,
- → advanced method for multidimensional data
- → using standard visualization tools (Matlab)

Data types in Evolutionary Algorithms

- individuals (solution vector)
  - → variables
  - → objective value(s)
- (sub) populations
  - → individuals
    - ⇨ variables of best individual
    - ⇨ objective value of best individual
    - ⇨ variables of all individuals
    - ⇨ objective value of all individuals
  - → distance between individuals
- different time frames
  - → one generation
  - → multiple / all generations
  - → multiple runs

Standard set

Overview

Visualization of the **course** of the EA

- objective value of best individual of every generation (convergence diagram)
- variables of best individual of every generation
- objective value of all individuals of every generation

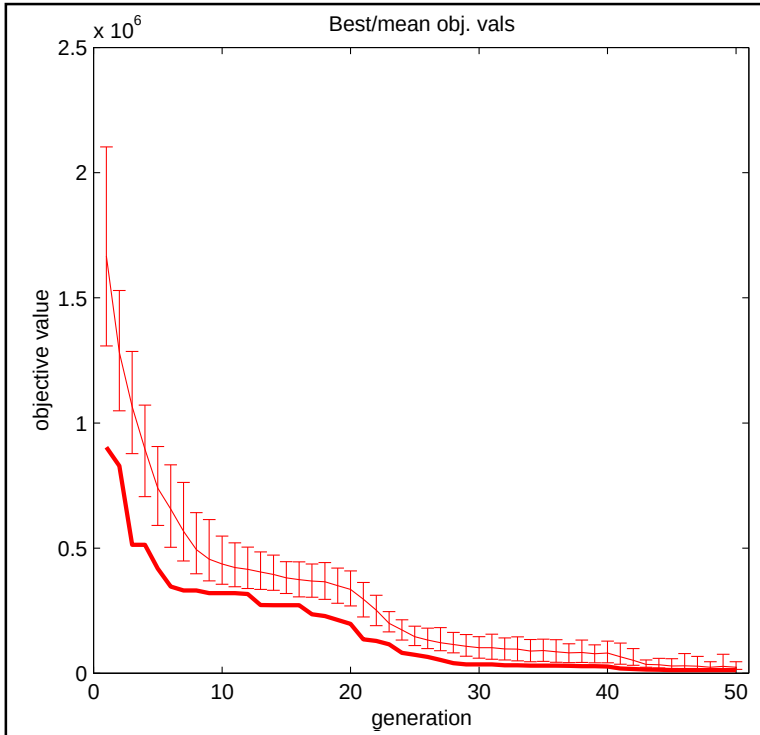
Visualization of the **state** of the EA

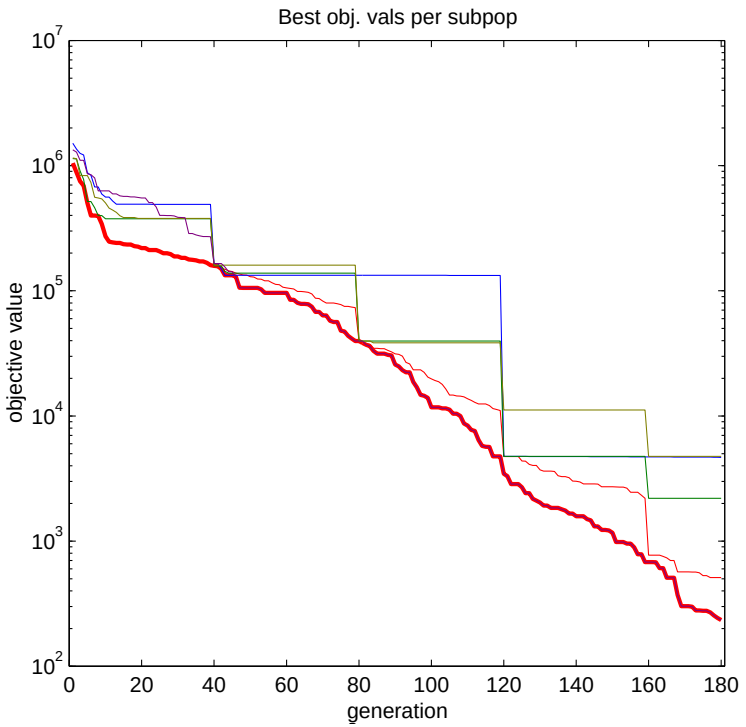
- objective value of all individuals
- variables of all individual
- (distance map of objective values / variable values)

Standard set

Course - Best objective value

Best objective value (convergence diagram)



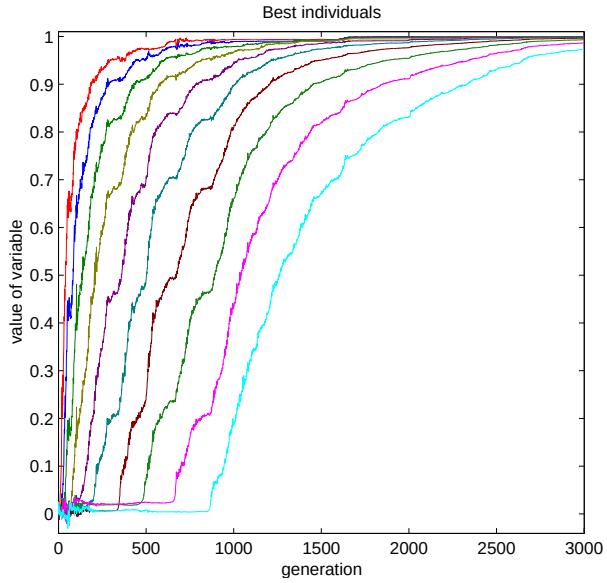


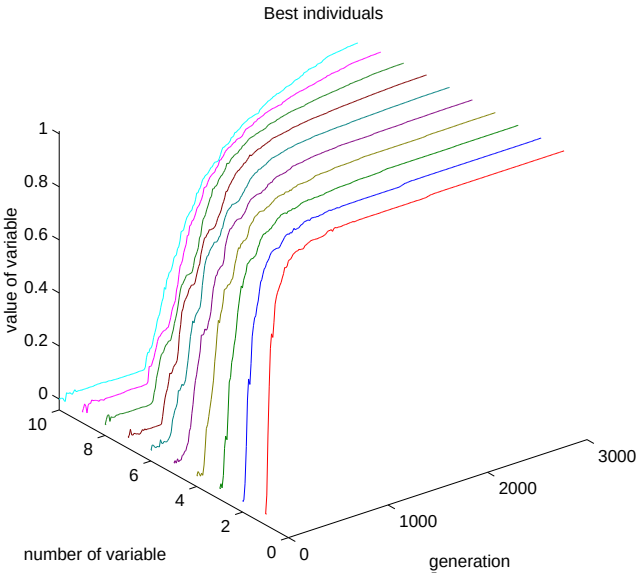
- very often used
- good impression of convergence (depends on scaling)
- extension for regional population model / use of different strategies

Standard set

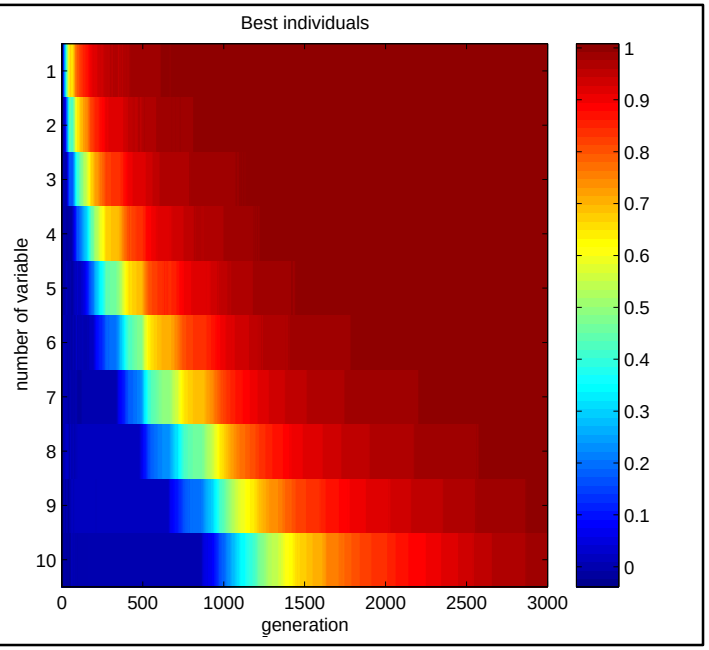
Course - Variables of best individual

Variables of best individual (all generations)





- one of the most representative graphics
- visualization of variable changes
- visualization of successful variables
- ROSENBROCK's function



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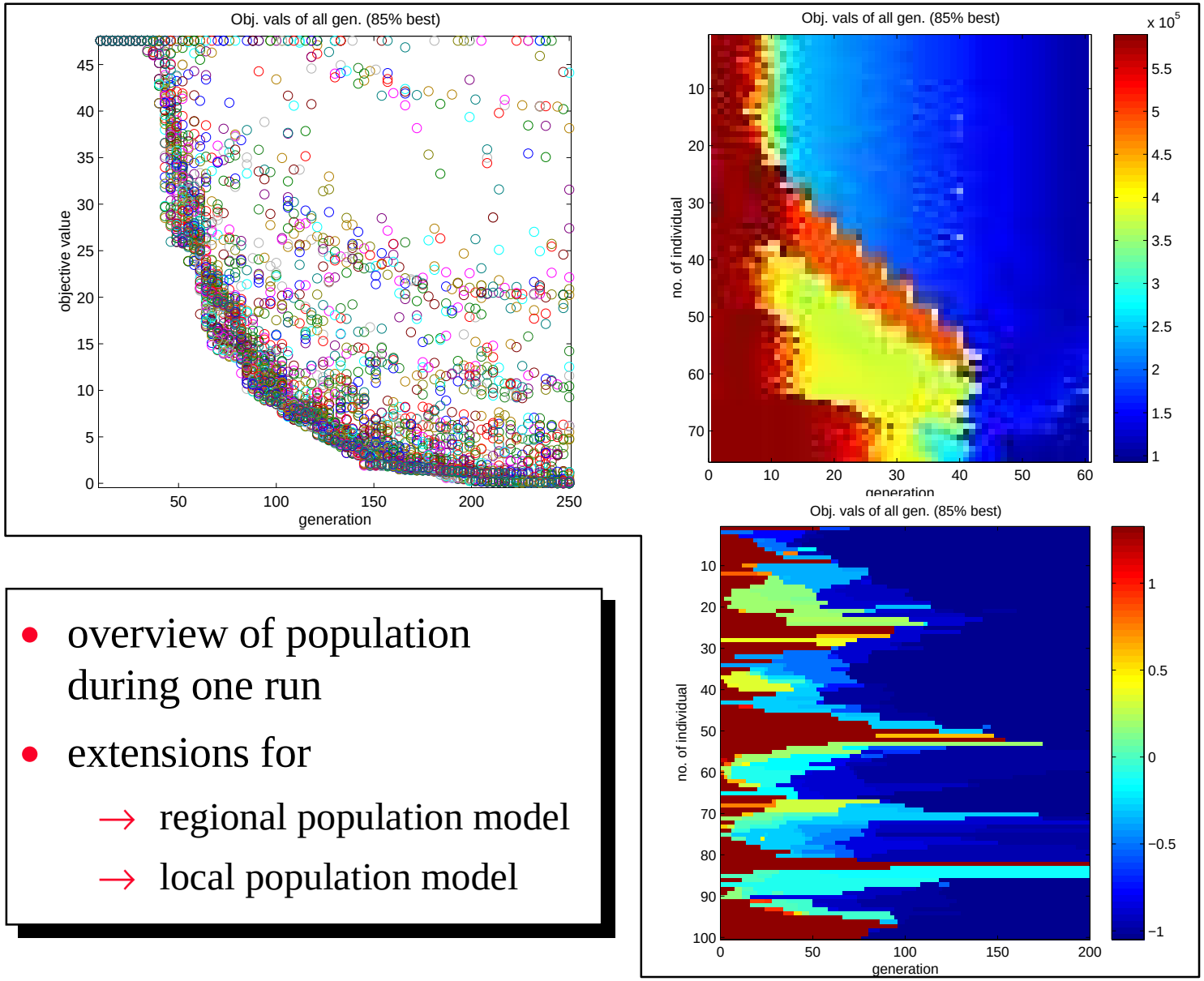
Standard set

Course - All objective values

Objective values of all individuals (all generations)



- overview of population during one run
- extensions for
  - → regional population model
  - → local population model

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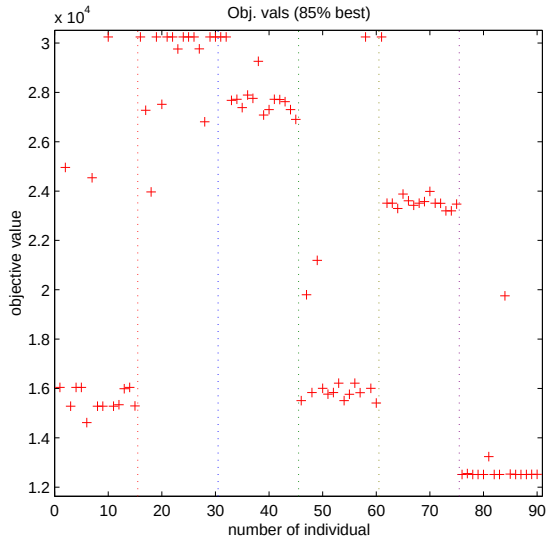
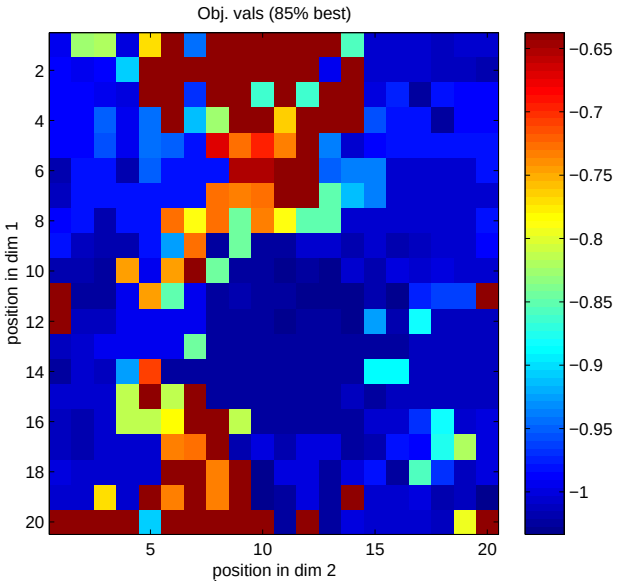
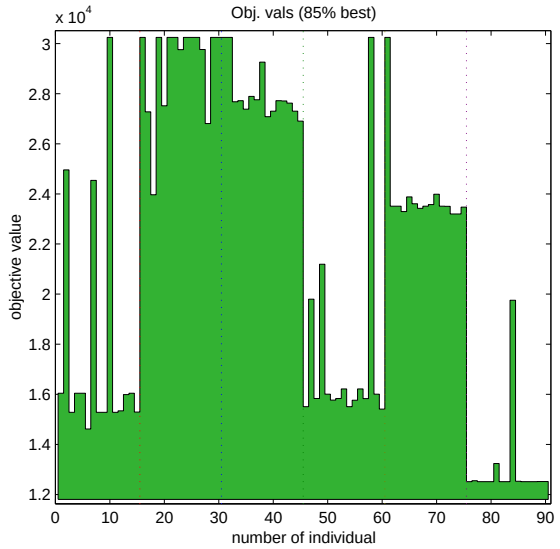
Standard set

State - All objective values

All objective values (one generation)





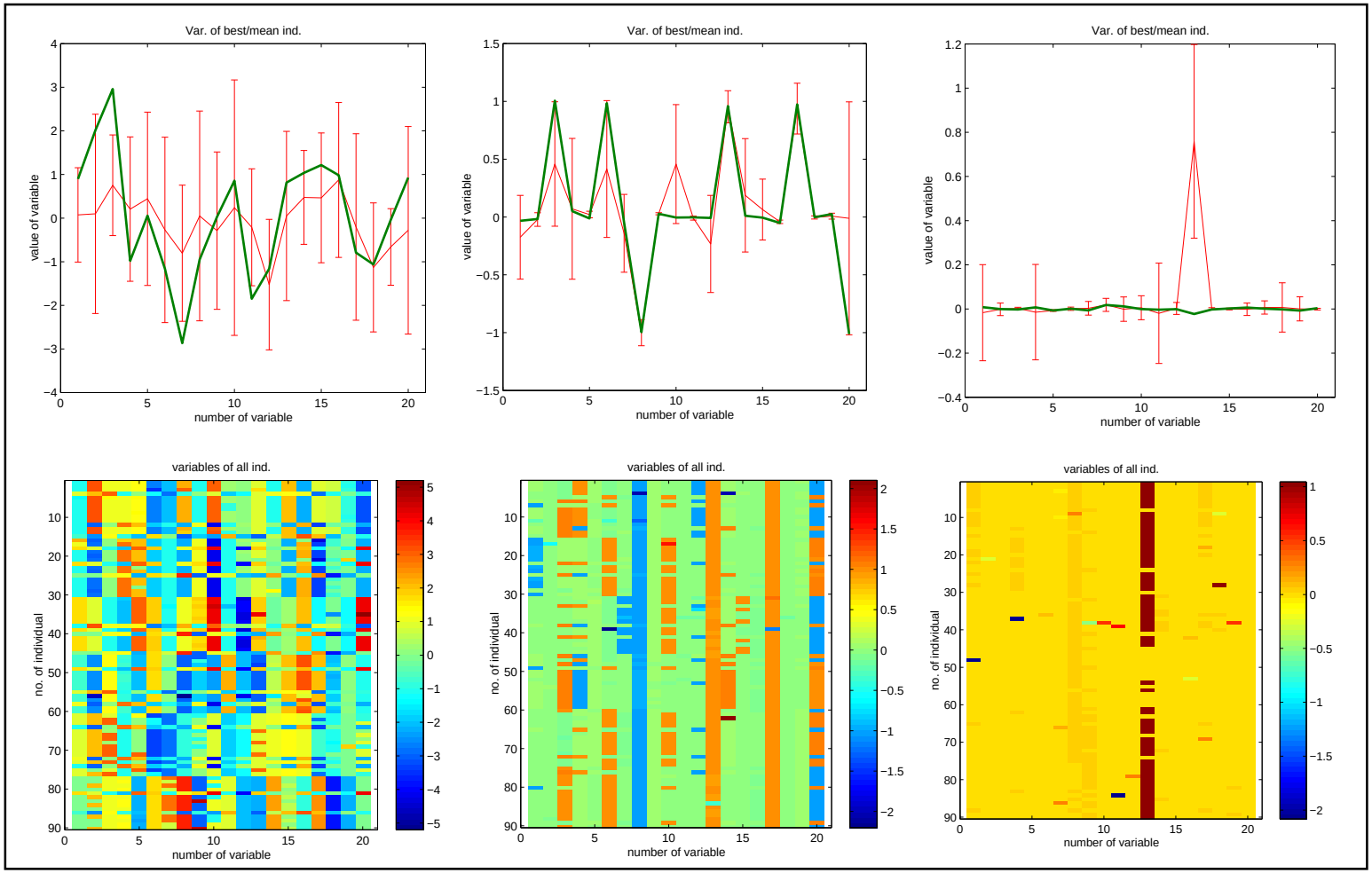


- good impression of the state of the population
- extension for regional and local model

Standard set

State - Variables of all individuals

Variables of all individuals (one generation)



- good impression of the state of the population

Multidimensional visualization

Motivation

- limitation for standard visualization to three dimensions
- extension to 4 or 5 dimensions is difficult to use

Solution

- transformation of multidimensional data to a lower dimension (2 or 3 dimensions)
- preserve dissimilarities between data points

→ ‘multidimensional scaling’

Multidimensional scaling

- Dissimilarities
  - → distance between points (Euclidean distance)

  $x_1,\ldots,x_n$: data points in $\Re^p$ $\quad$ δ_{ij}: distance between x_i und x_j

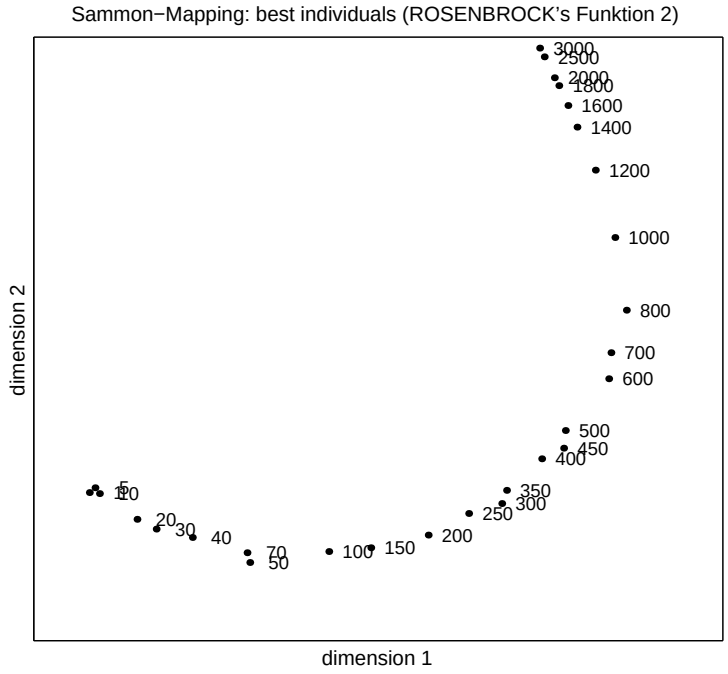
  $y_1,\ldots,y_n$: data points in $\Re^q$, $p \geq q$ $\quad$ d_{ij}: distance between y_i und y_j
- search for a low-dimensional configuration, with
  - → distances between data points similar to distances in high-dimensional configuration
  - → quality criterion: $$J_{ef} = \frac{1}{\sum_{i<j}\delta_{ij}} \sum_{i<j} \frac{\left(d_{ij}-\delta_{ij}\right)^2}{\delta_{ij}}$$
- optimization by:

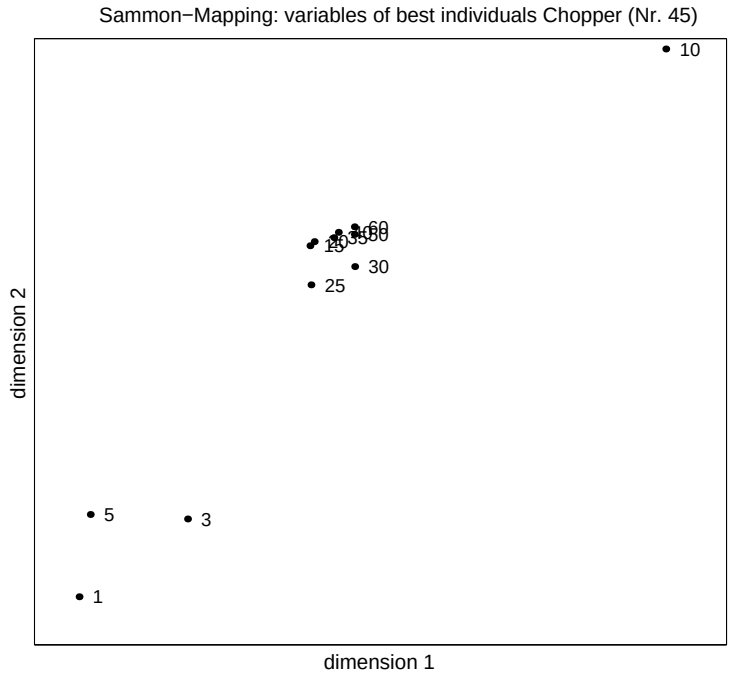
$$\nabla_{y_k} J_{ef} = \frac{2}{\sum_{i<j}\delta_{ij}} \sum_{j\neq k} \left(\frac{d_{kj}-\delta_{kj}}{\delta_{kj}} \cdot \frac{y_k - y_j}{d_{kj}} \right)$$

  - → gradient based optimization (from Matlab)
  - → more robust search: RPROP - just change of sign of gradient

Variables of best individual

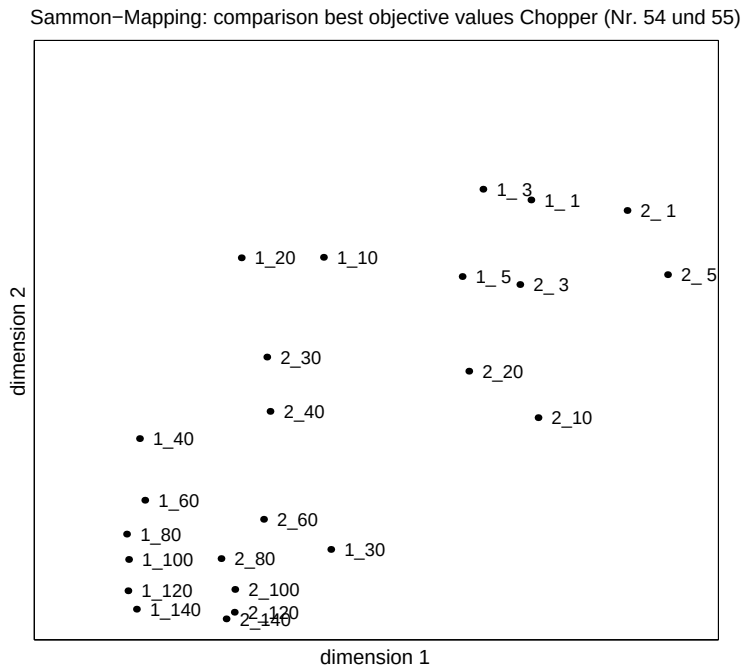
- “path through search space” of best individual
- additional information compared to standard plot
- better understandable picture than standard plot

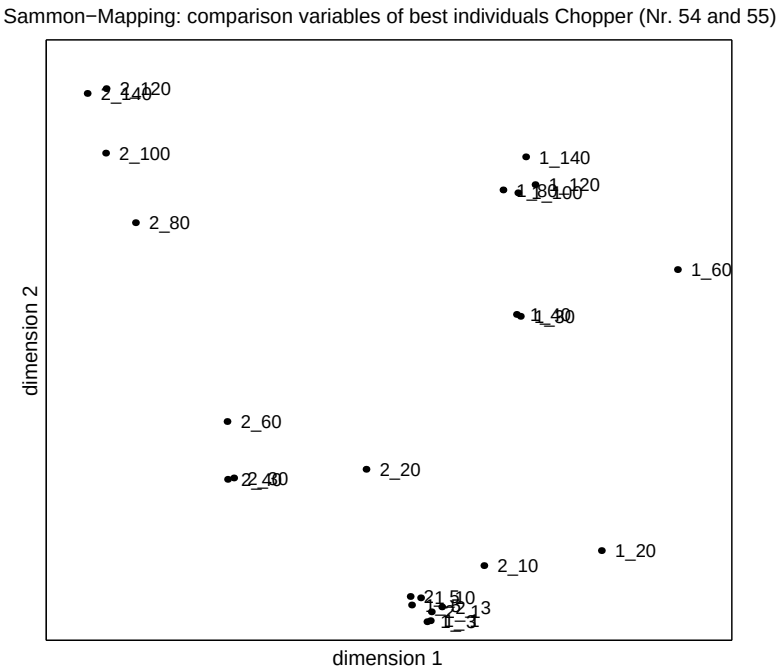




Multiple objective values of best individual

- comparison of two optimization runs
  - → multi criteria objective values
  - → variables of corresponding individuals





Summary

Advantages

- proposal of set of visualization methods
  - → methods for the course / progress of the EA
  - → methods for the state of the population
- base line for understanding the evolutionary process
- provides insight into the work of the EA
- powerful visualization tools to aid the designer and user of Evolutionary Algorithms
- application of presented techniques to real world problems
  - → proved useful and informative

→ example implementation in

"Genetic and Evolutionary Algorithm Toolbox for use with Matlab"
www.systemtechnik.tu-ilmenau.de/~pohlheim/GA_Toolbox/index.html