Visualization of Evolutionary Algorithms - Set of Standard Techniques and Multidimensional Visualization

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Overview

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

Motivation

Introduction

Evolutionary Algorithms

- → work with simple algorithms
- → produce vast amount of data

Problem:

extraction of useful information to provide insight into

- → state of the population,
- → progress of the Evolutionary Algorithm

⇒ Visualization of data

Goals:

- → set of standard methods for different data types,
- → advanced method for multidimensional data
- → use of standard visualization methods and tools (MATLAB)

Data types in Evolutionary Algorithms

- individuals (solution vector)
  - → variables
  - → objective value(s)
- (sub) populations
  - → individuals
    (variables / objective values of best / all individuals)
  - → distance between individuals
  - → ranking / order and size of subpopulations
- different time frame
  - → one generation ⟹ state of EA
  - → multiple / all generations ⟹ course of EA
  - → multiple runs ⟹ comparison of EA

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

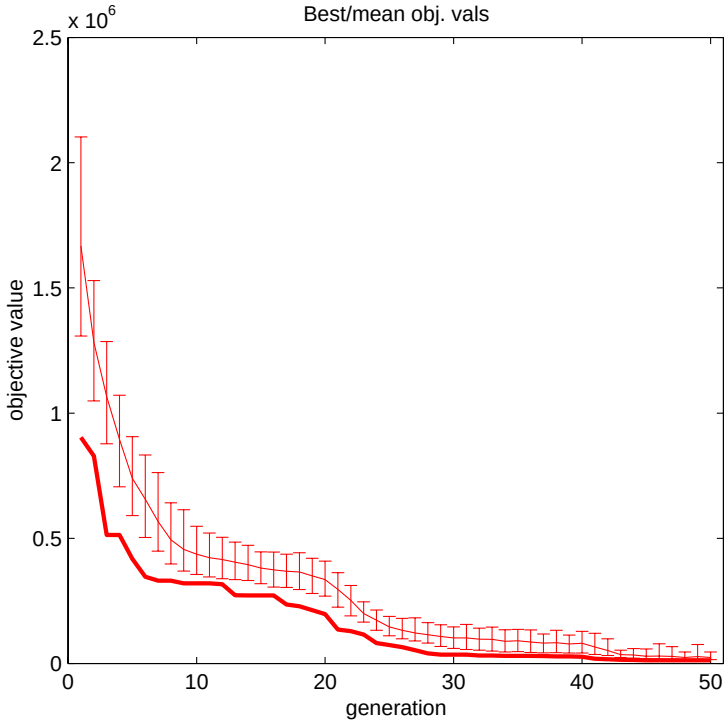
Visualization of the state of the EA

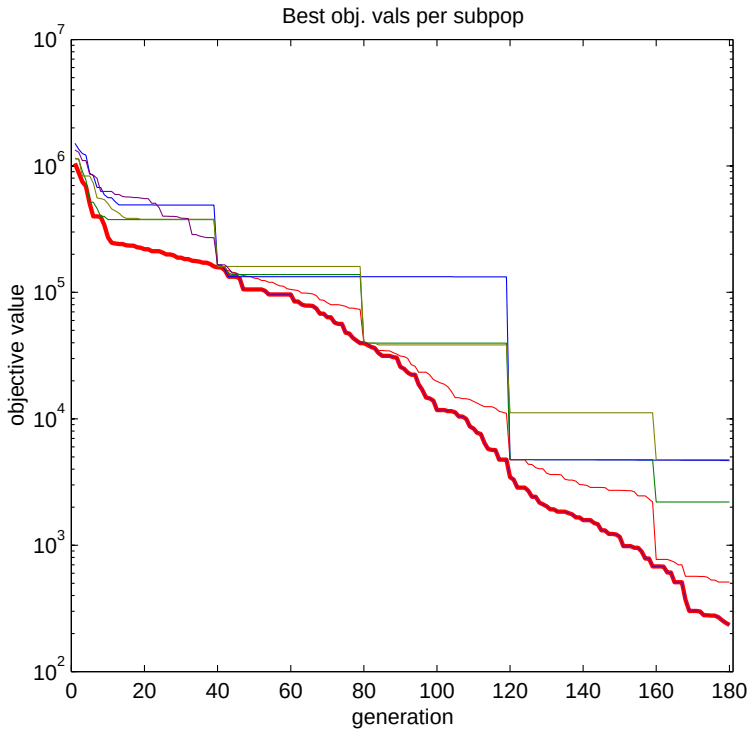
- objective value of all individuals
- variables of all individuals
- (distance map of objective values / variable values)

Standard set

Course - best objective value

Objective value of best individuals (convergence)



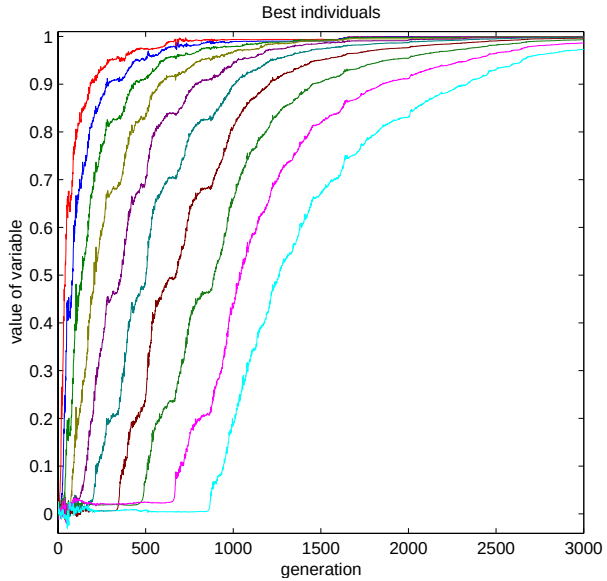


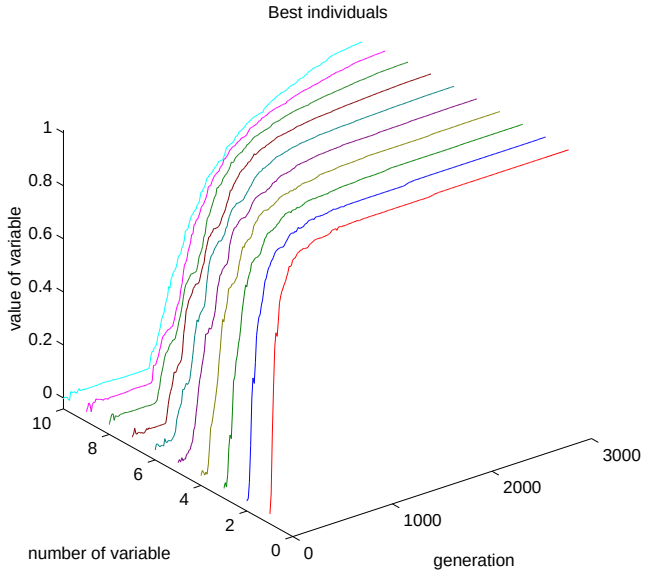
- very often used
- visual impression of convergence (depends on scaling)
- extension for regional population model and for use of different strategies (right diagram)

Standard set

Course - variables of best individual

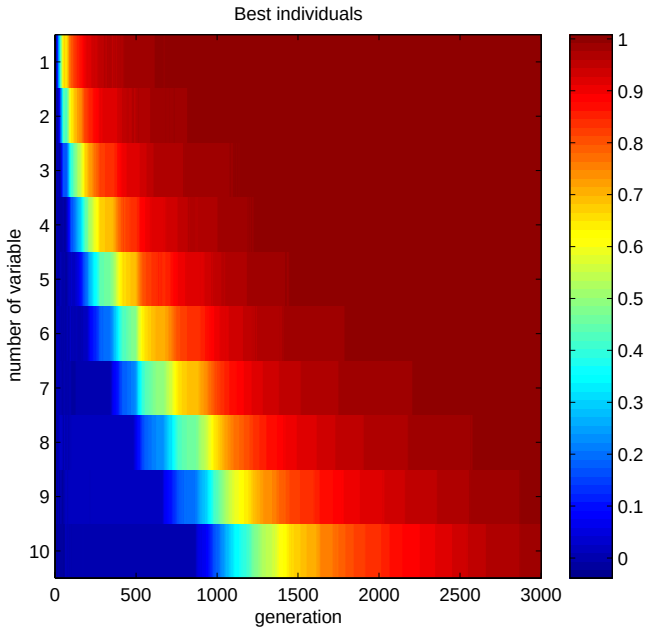
Variables of best individual (all generations)





- one of the most representative graphics
- visualization of variable changes
- visualization of successful variables

(ROSENBROCK's function)



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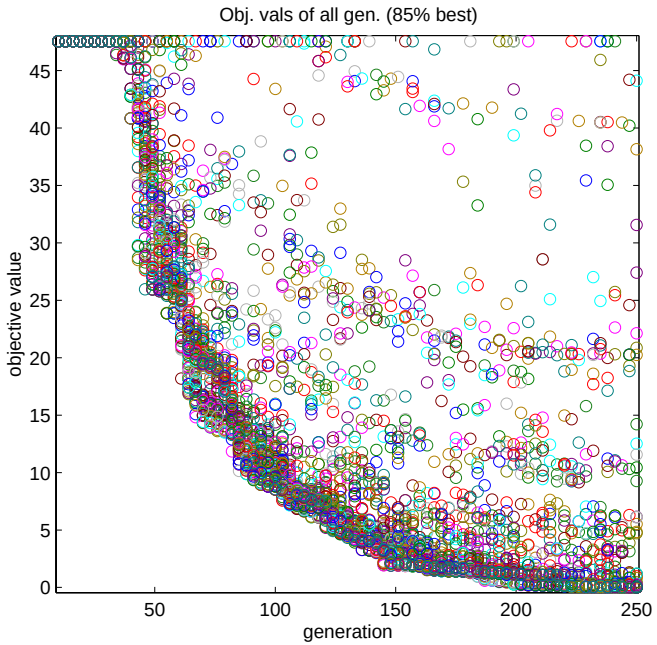
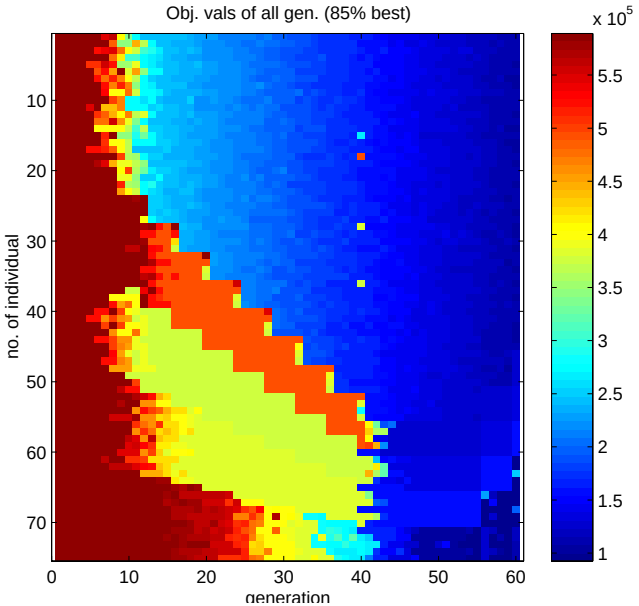
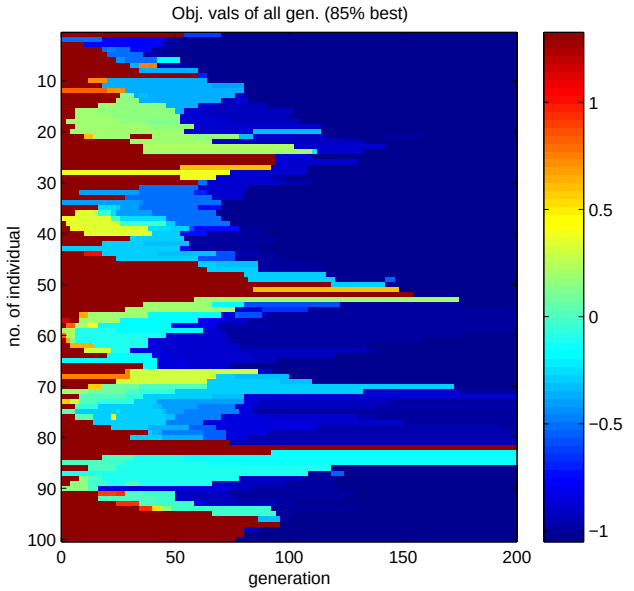
Standard set

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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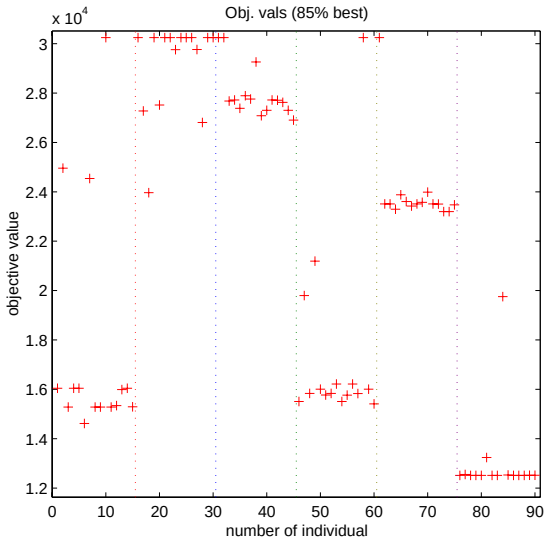
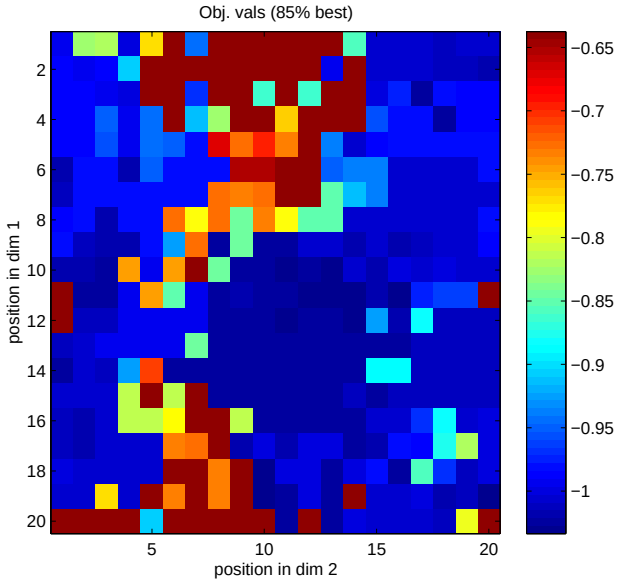
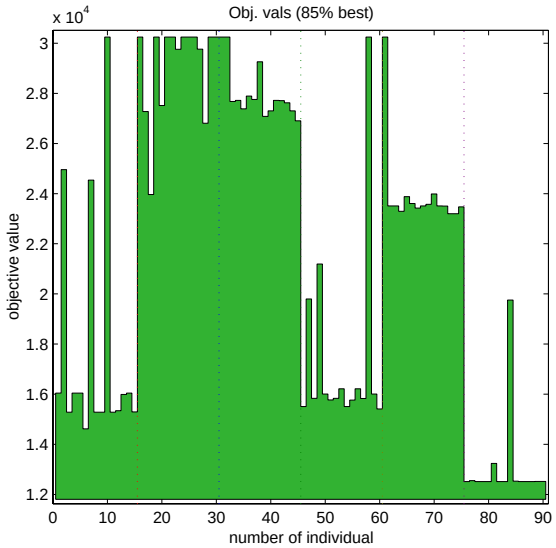
Standard set

State - all objective values

All objective values (one generation)





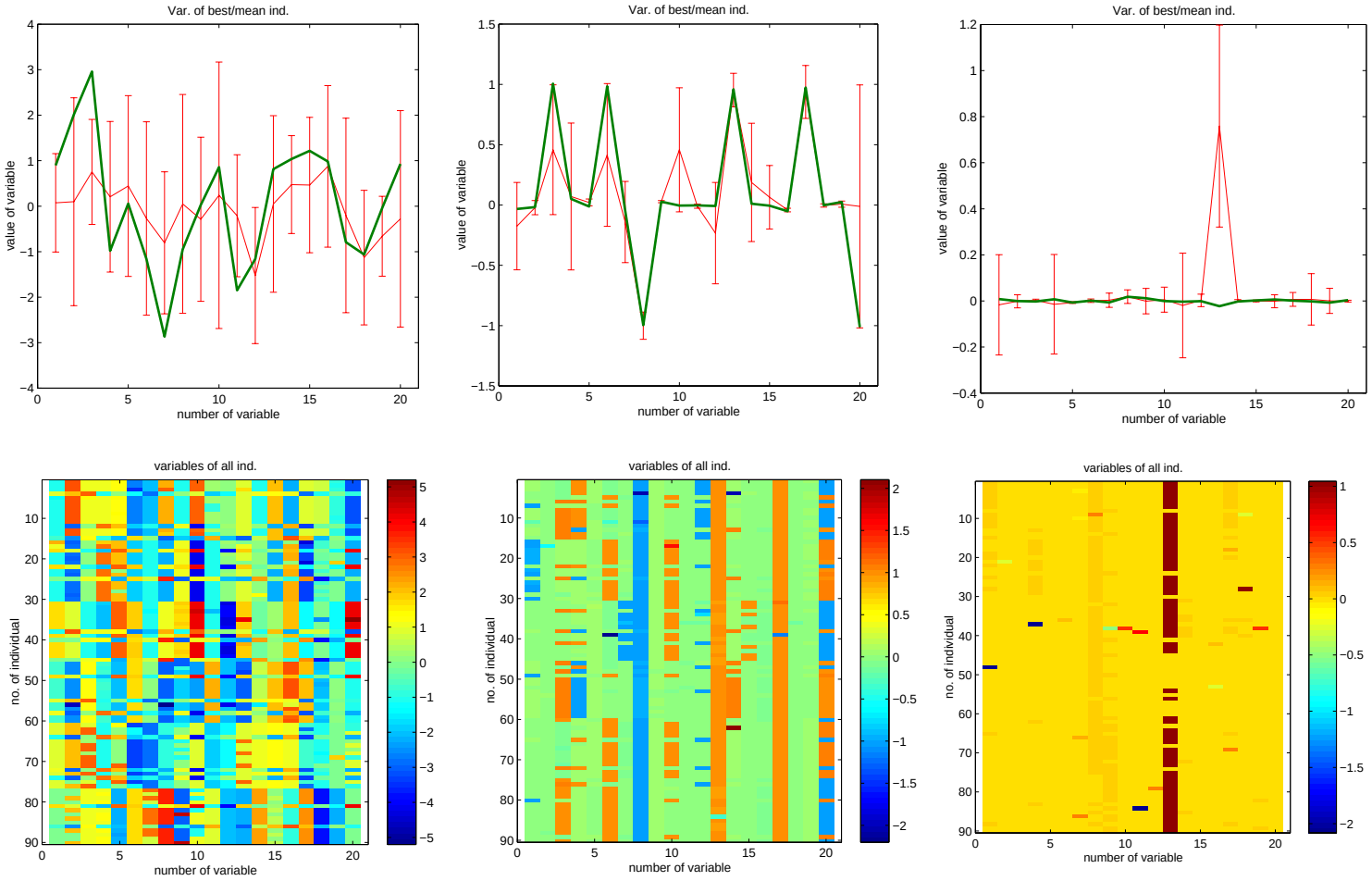


- visual impression of the state of the population
- extension for regional and local model

Standard set

State - variables of all individuals

Variables of all individuals (one generation)



- visual impression of the state of the population

Visualization of high-dimensional data

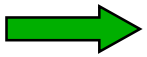
Motivation

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

(color and time)

Problem:

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



‘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: $$J_{ef} = \frac{1}{\sum_{i<j}\delta_{ij}} \sum_{i<j} \frac{\left(d_{ij}-\delta_{ij}\right)^2}{\delta_{ij}}$$

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

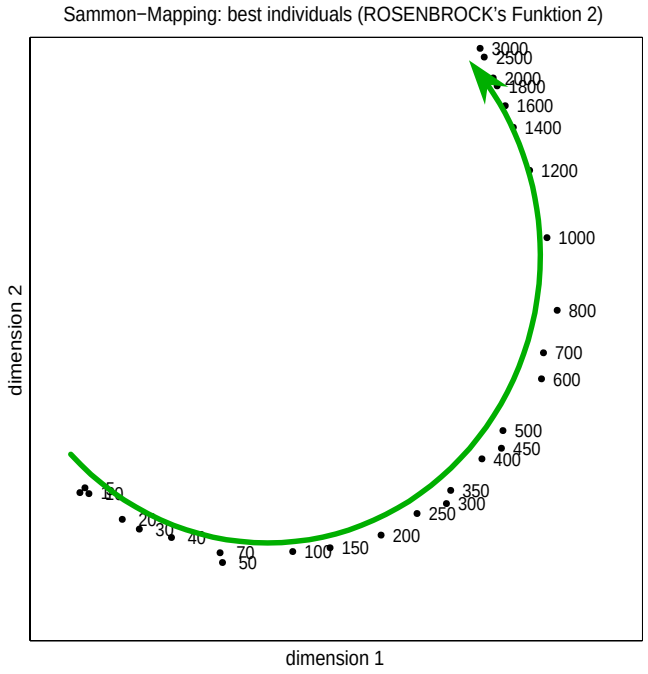
- optimization by:
  - → gradient based optimization (from Matlab)
  - → more robust search: RPROP - only change of sign of gradient

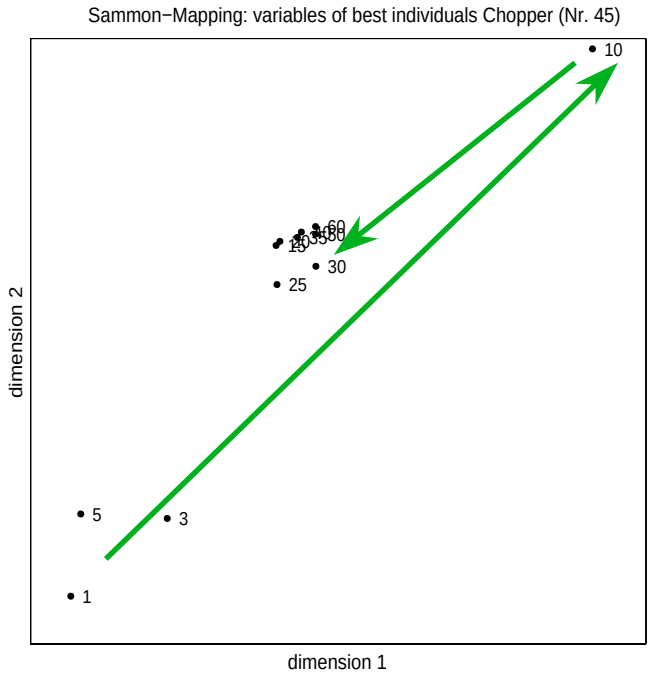
Advanced visualization

Example

Variables of best individual

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

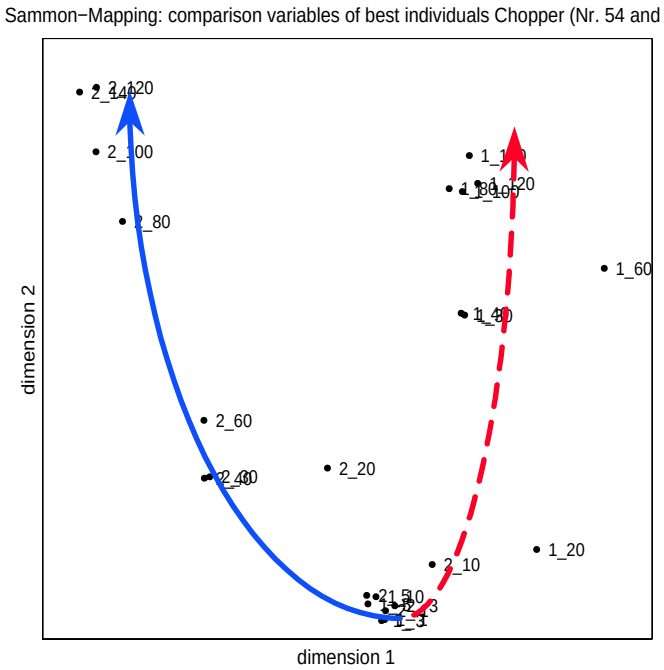


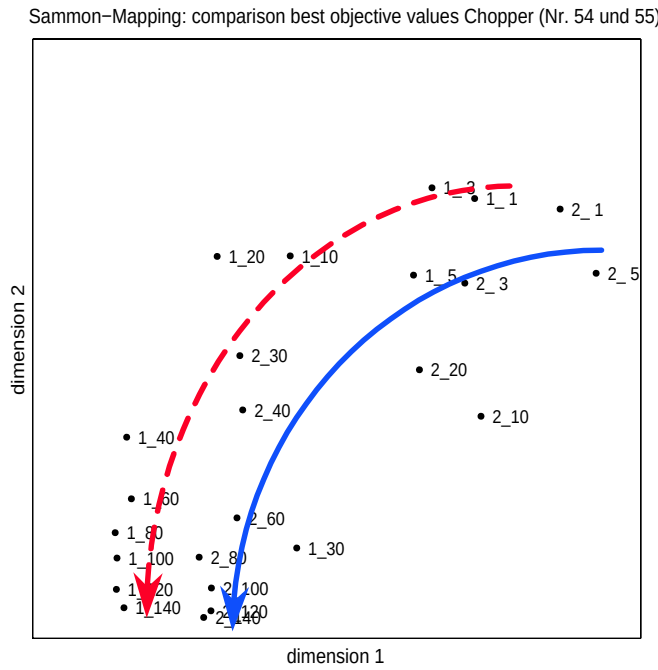


Comparing two optimization runs

- comparing optimization runs
  - → variables of best individuals ("path through search space")
  - → multi criteria objective values ("path through solution space")

  1. run: red paths 2. run: blue paths





Summary

Advantages

- Proposal of set of visualization methods
  - → methods for the course / progress of the EA
  - → methods for the state of the population
  - → methods for high-dimensional visualization

Advantages:

- → baseline for understanding the evolutionary process
- → insight into the work of the Evolutionary Algorithm
- → powerful visualization tools to aid the designer and user of Evolutionary Algorithms

- application to real world problems proved successful
- example implementation

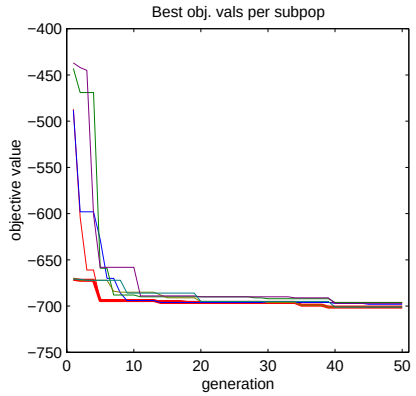
  "Genetic and Evolutionary Algorithm Toolbox for use with Matlab"
  http://www.geatbx.com/index.html

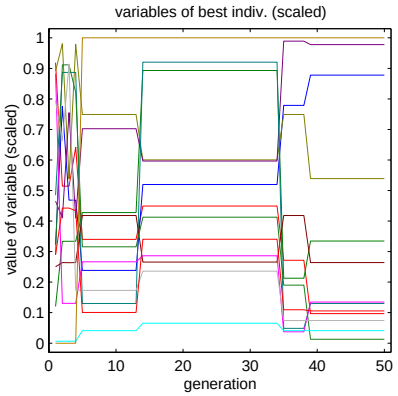
Application

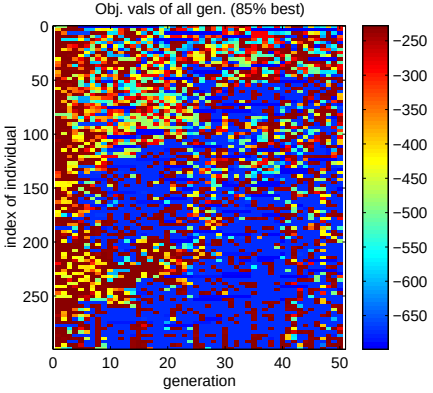
Real world system

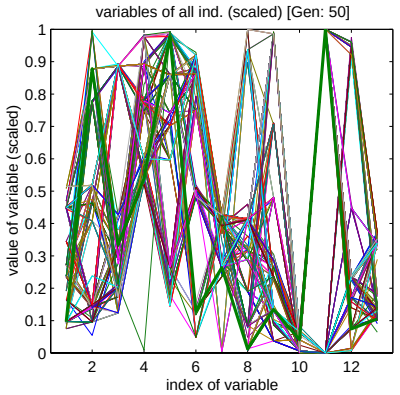
Application to real world problems

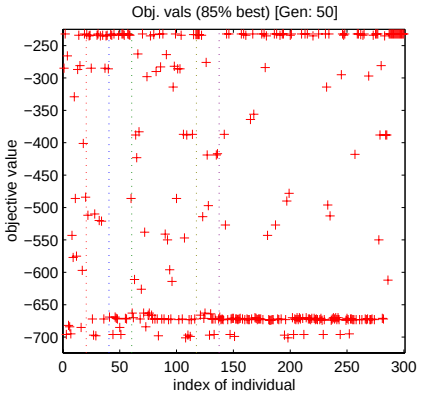
- Use of visualization methods for analysis of optimization run (optimization of real time system for maximal run time)

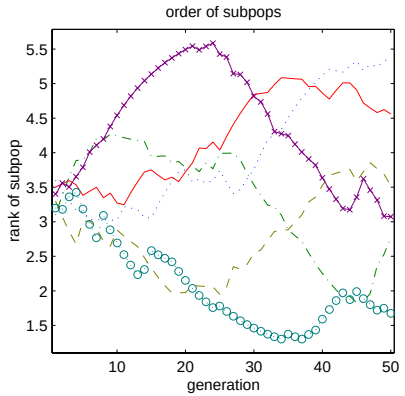












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Application

Graphical user interface

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Graphical User Interface for visualization methods

- access to all visualization methods and styles during and after an optimization (corresponds with diagram on previous slide)