Visualization of Evolutionary Algorithms

Hartmut Pohlheim, DaimlerChrysler AG, Research and Technology, FT3/SM, Berlin

1 Motivation

- Evolutionary Algorithms (EA) exhibit a complex behavior by combination of algorithmically simple methods
- EA produce vast amount of data by recurring processes

Problem:

selection, concentration and abstraction of data to gain insight into state, course and results of EA

➡ Visualization of data

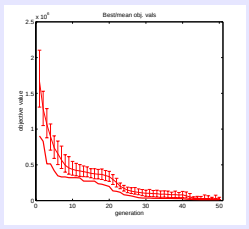
Goal: visualization methods for real world application

2 Systematization

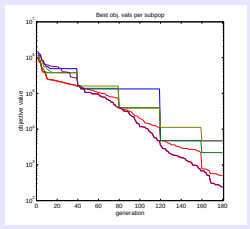
	direct values			derived values
	single individuals	**subpopulations**	**population**	**population**
one / current generation	• variables of best individual	• size and ranking of subpopulations	• variables of individuals • objective values of individuals	• distance distribution • distance map • fitness-allele-quilt
multiple generations	• variables and • objective value of best individuals	• size and ranking of subpopulations	• convergence: objective value of best individual	• convergence: mean obj. value, standard deviation of obj. val. • statistics: diversity, fixing, inbreeding, classes
multiple runs	• best objective value per run • best individual per run	• best subpopulation / strategy per run	• number of generations / objective function calls to reach optimum of run • number of successful runs	• influence of changing parameters to success of EA

3 Course / Progress of EA

Objective values of best individuals from multiple generations



2-D line: best objective value plus mean and standard deviation of all objective values

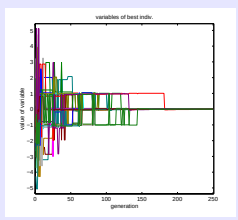


2-D line logarithmic: best objective value plus objective values of best individuals of each subpopulation - regional model

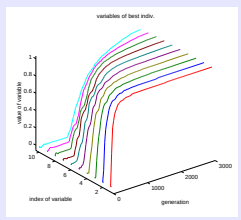
- essential visualization in analysis
- assessment of improving objective values in the course of generations (covergence diagram)
- extension for regional model:
  - success of every subpopulation
  - effect of migration

Variables of best individuals from multiple generations

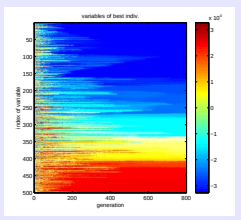
- course of variable alterations
  - discrete changes of variable values
  - correlation between variables
- successful variable values perceptible



2-D line: basic method (RASTRIGIN's function 6)

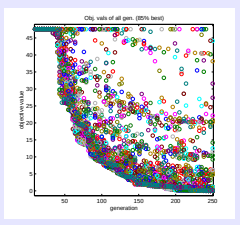


3-D line: allocation of variable numbers possible (ROSENBROOK's function 2)

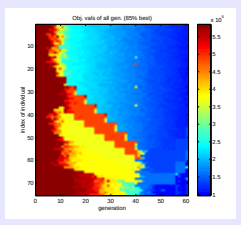


2-D color quilt: very good for many variables (execution time bubble sort modul)

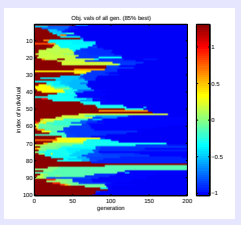
Objective values of all individuals from multiple generations



2-D point: basic method, not more than an impression of distribution of objective values



2-D color quilt: allocation of individuals possible, change of size of competing subpopulations recognizable

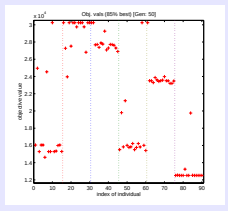


2-D color quilt: application of local population model ("diffusion" in small neigborhood)

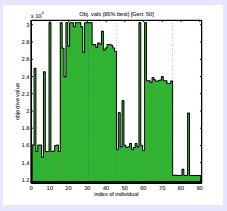
- insight into distribution of objective values
- propagation of good individuals
- "division" of population (regional and local population model)

4 State of population

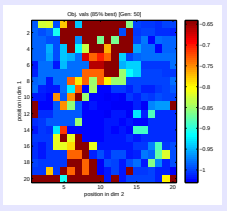
Objective values of all indiviuals within one generation



2-D point: distribution of objective values in subpopulations



2-D stairs: size of competing subpopulations recognizable

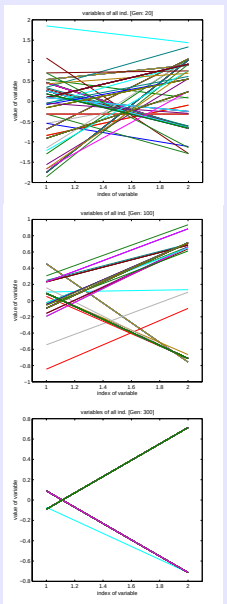


2-D color quilt: "diffusion" when employing 2-D local model

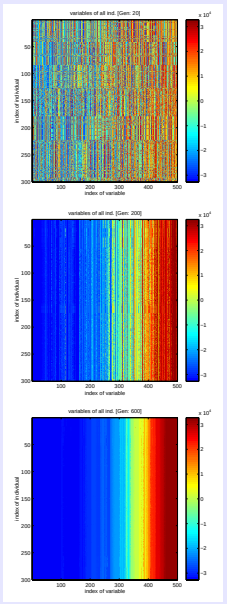
- image of state of the population
- insight into distribution and propagation of objective values
- extensions for regional and local model

Variables of all individuals within one generation

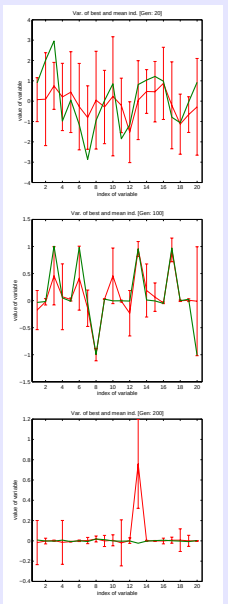
- image of phenotype of individuals
- deep insight into state of population
- assessment of distribution and/or similarity of variable values
- restriction of variables to few promising areas
- creation of clusters indicating multimodal function (left diagrams)
- distribution of values inside subpopulations - regional population model (top middle diagram)



2-D line: distribution of variable values and creation of clusters (*six hump camelback* function)

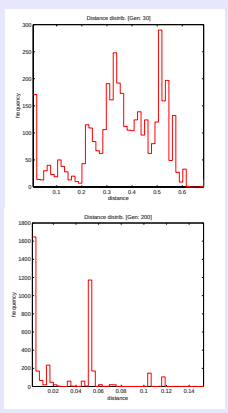


2-D color quilt: allocation of each individual possible (execution time bubble sort modul)

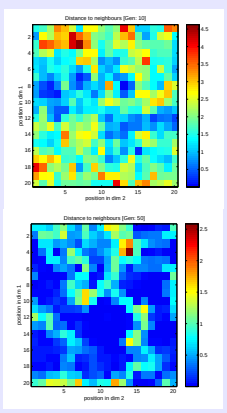


2-D line: including best individual, mean of all individual and standard deviation (RASTRIGIN's function 6)

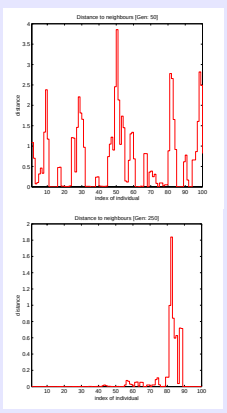
Distance between individuals within one generation



2-D stairs: distance distribution - distance between all individuals



2-D color quilt: distance map for two-dimensional local population model



2-D stairs: distance map for one-dimensional local population model

- image of distance between individuals
  - distance distribution: distance between individuals of population
  - distance map: distance between neighbors (local population model)
- shows diversity of population
- recognition of cluster creation

top graph: begin of run

bottom graph: during the run

5 Multidimensional visualization

- standard methods are limited to 3 dimensions
- extension to 4 or 5 dimensions difficult to use (color and time)

Problem: transformation of high-dimensional data, $\boldsymbol{X}$, into lower dimension

➡ 'multidimensional scaling'

- search for low-dimensional configuration $\boldsymbol{Y}$
- dissimilarities between the data points in $\boldsymbol{Y}$ similar to the high-dimensional configuration $\boldsymbol{X}$ ($\rightarrow$ Qualitätskriterium)
- optimization problem ($\rightarrow$ minimization quality criterion)
- gradient known ($\rightarrow$ gradient-based search)

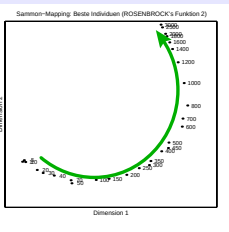
$\boldsymbol{X}$: $x_1, \ldots, x_n$: data points in $\Re^p$ $\quad \delta_{ij}$: distance between x_i und x_j

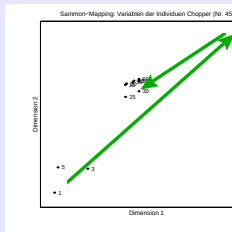
$\boldsymbol{Y}$: $y_1, \ldots, y_n$: data points in $\Re^q$, $p \geq q$ $\quad d_{ij}$: distance between y_i und y_j

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

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

Variables of best individuals from multiple generations





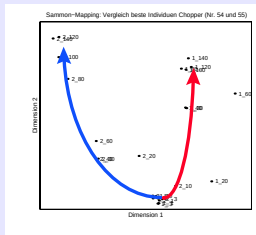
- "path through search space" of best individuals
- additional information to standard plot
- sometimes easier to interpret than standard plot

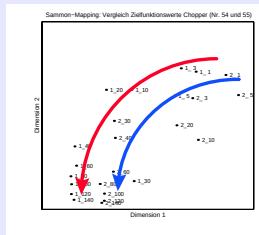
Comparing multiple optimization runs

- comparison regarding:
  - variables of best individuals ("path through search space")
  - multiple objective values ("path through solution space")

run 1: red paths

run 2: blue paths





6 Summary

- proposal of visualization methods
  - $\rightarrow$ methods to visualize course / progress of Evolutionary Algoritm
  - $\rightarrow$ methods to visualize state of the population
  - $\rightarrow$ methods for multidimensional data

Advantages

- $\rightarrow$ baseline for understanding evolutionary processes
- $\rightarrow$ provides insight into operation of the Evolutionary Algorithm
- $\rightarrow$ powerful visualization tool for the developer and user of Evolutionary Algorithms

- application to real world problems proved successful
- example implemetation:

  "GEATbx: Genetic and Evolutionary Algorithm Toolbox for Matlab" (www.geatbx.com)