WESTFÄLISCHE WILHELMS-UNIVERSITÄT MÜNSTER

ERCIS European Research Center for Information Systems

CURRENT RESEARCH ON EXPLORATORY LANDSCAPE ANALYSIS

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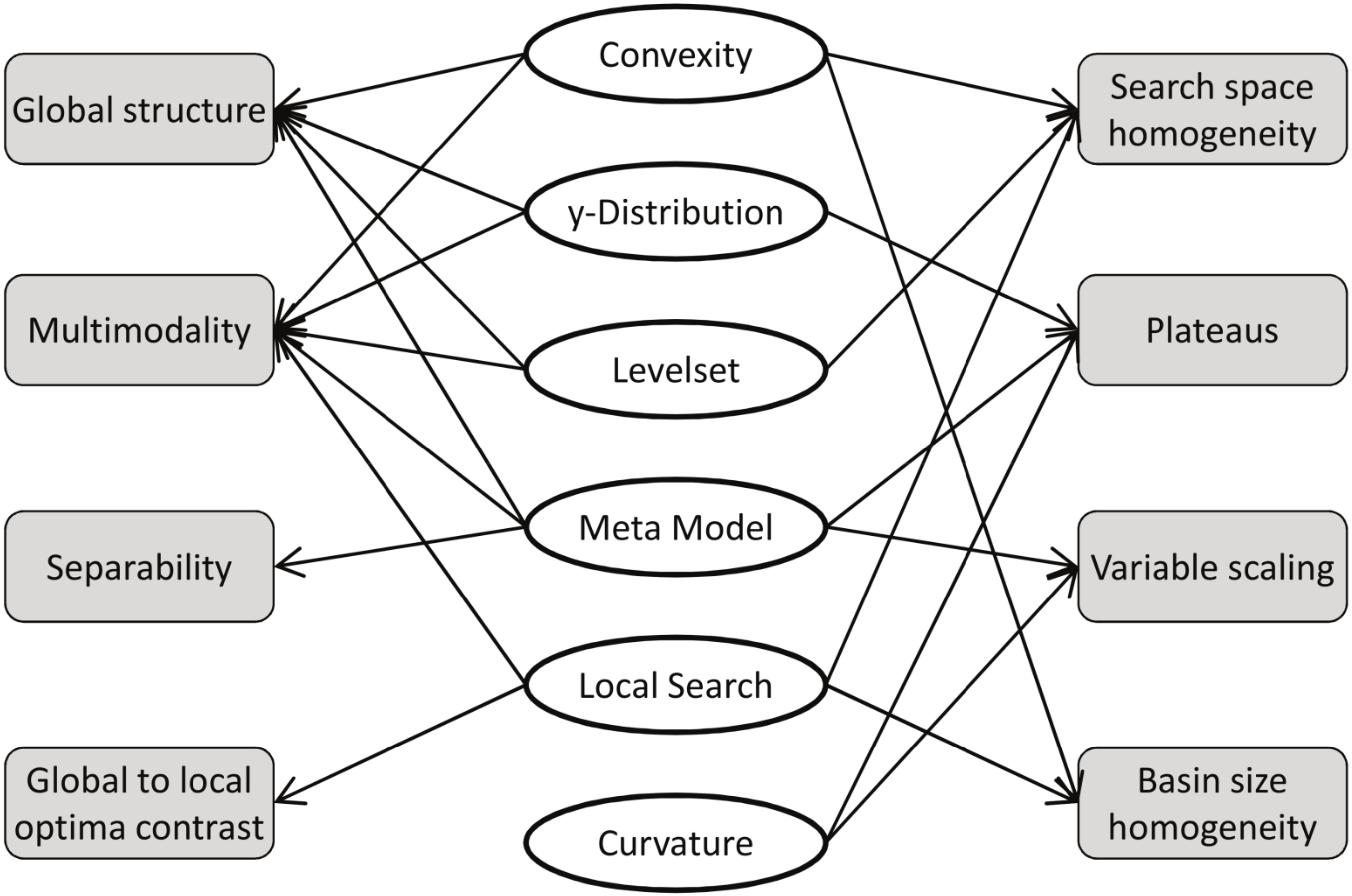
EXPLORATORY LANDSCAPE ANALYSIS

- effective and sophisticated approach to characterize properties of optimization problems
- overall aim: recommendation of individually best suited algorithm for unseen optimization problems (algorithm selection)
- research so far provides set of features that requires only small amount of (additional) function evaluations

FEATURES AND PROPERTIES



PAPER HISTORY

Kerschke, Preuss, Hernandez, Schütze, Sun, Grimme, Rudolph, Bischl, Trautmann. Cell Mapping Techniques for Exploratory Landscape Analysis. In *EVOLVE - A Bridge between Probability, Set Oriented Numerics, and Evolutionary Computation V*, Springer, 2014.

Bischl, Mersmann, Trautmann, Preuss. Algorithm selection based on exploratory landscape analysis and cost-sensitive learning. In *GECCO 2012*, pp. 313-320. ACM, 2012

Mersmann, Bischl, Trautmann, Preuss, Weihs, Rudolph. Exploratory Landscape Analysis. In *GECCO '11: Proceedings of the 13th annual conference on Genetic and evolutionary computation*, pp. 829-836, 2011.

Mersmann, Preuss, Trautmann. Benchmarking Evolutionary Algorithms: Towards Exploratory Landscape Analysis. In *Parallel Problem Solving from Nature – PPSN XI, Proceedings, Lecture Notes in Computer Science, Volume 6238/2011*, pp. 73-82, Springer, 2011

Bartz–Beielstein, Preuss. Experimental Analysis of Optimization Algorithms: Tuning and Beyond. In *Theory and Principled Methods for Designing Metaheuristics*, Springer, 2013.

PREVIOUS RESULTS 2011-2013

- ELA features enable selecting good algorithm from a portfolio
- algorithm selection works remarkably well for new functions

(evaluated by leave-one-function-out cross-validation)

- some low-level feature groups (local search and curvature) need many additional evaluations -> find cheaper features
- some properties (global structure, multi-modality and variable scaling) important for characterization of problem landscape -> find cheaper features for those properties

ELA WITH CELL MAPPING FEATURES

(EVOLVE PAPER 2014)

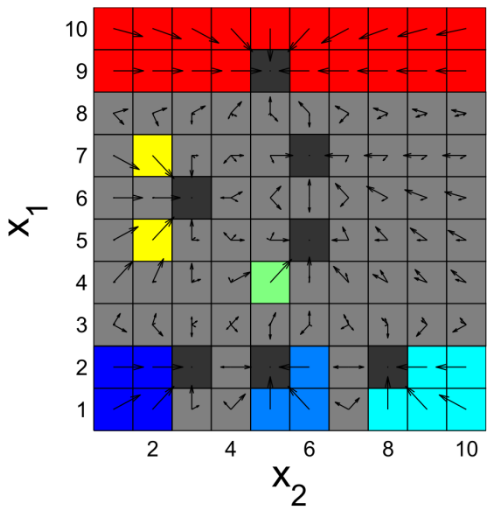
- overall task: improvement of existing feature set
- new features based on cell mapping concept
- only small (initial) problem sample
- no new cost when used together with original ELA features
- focus on better capturing important high-level properties (multi-modality, global structure)

(GENERALIZED) CELL MAPPING

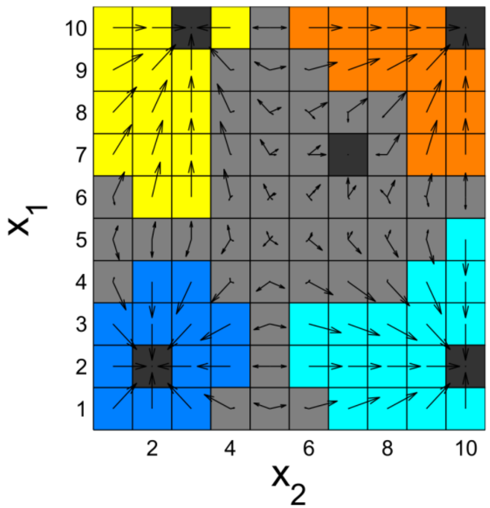
- discretize search space into hypercubes
- 1000 observations randomly distributed over 10x10 cells
- overall idea: differences between cells provide new insight
- each cell represented by prototype according to 3 aggregations methods:
  - minimum function value
  - mean of objective values
  - objective of point closest to cell center
- 2 new feature groups:
  - 32 generalized cell mapping features
  - 12 features based only on discretization into hypercubes

GCM FEATURES

- we estimate transition probabilities via sampling
- related to Markov chains: attractor cells, certain transient cells (to 1 attractor), uncertain transient cells (to *n* attractors)
- derive GCM features: number of attractors, basin sizes, etc.

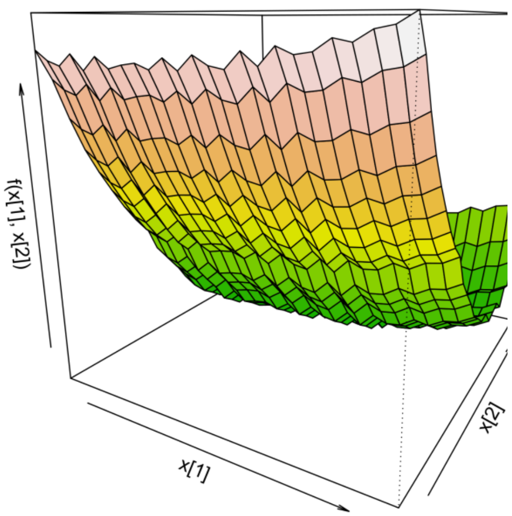


Griewangk 2D

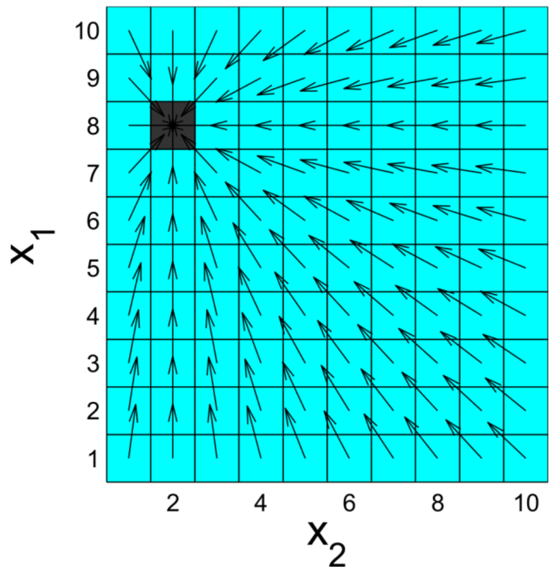


Schwefel 2D

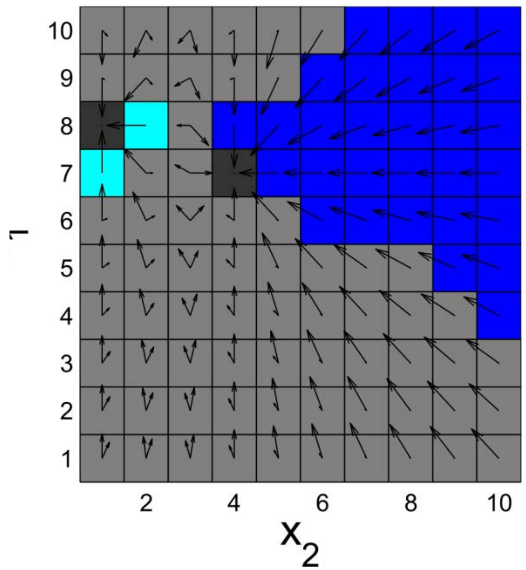
EXAMPLE: RASTRIGIN FUNCTION



cell topology



minimum approach

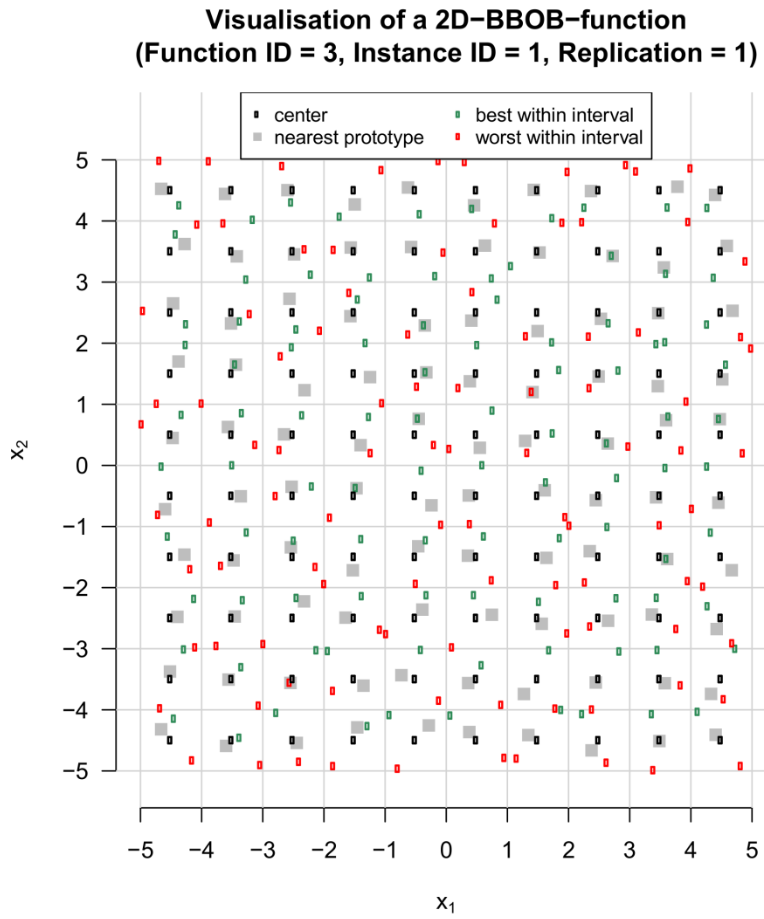


average approach

GCM FEATURE PROBLEMS

- need enough samples per cell
- a lot of information is not used
- difficult to transfer to 3+ D

-> strong need for more features that exploit the sample better



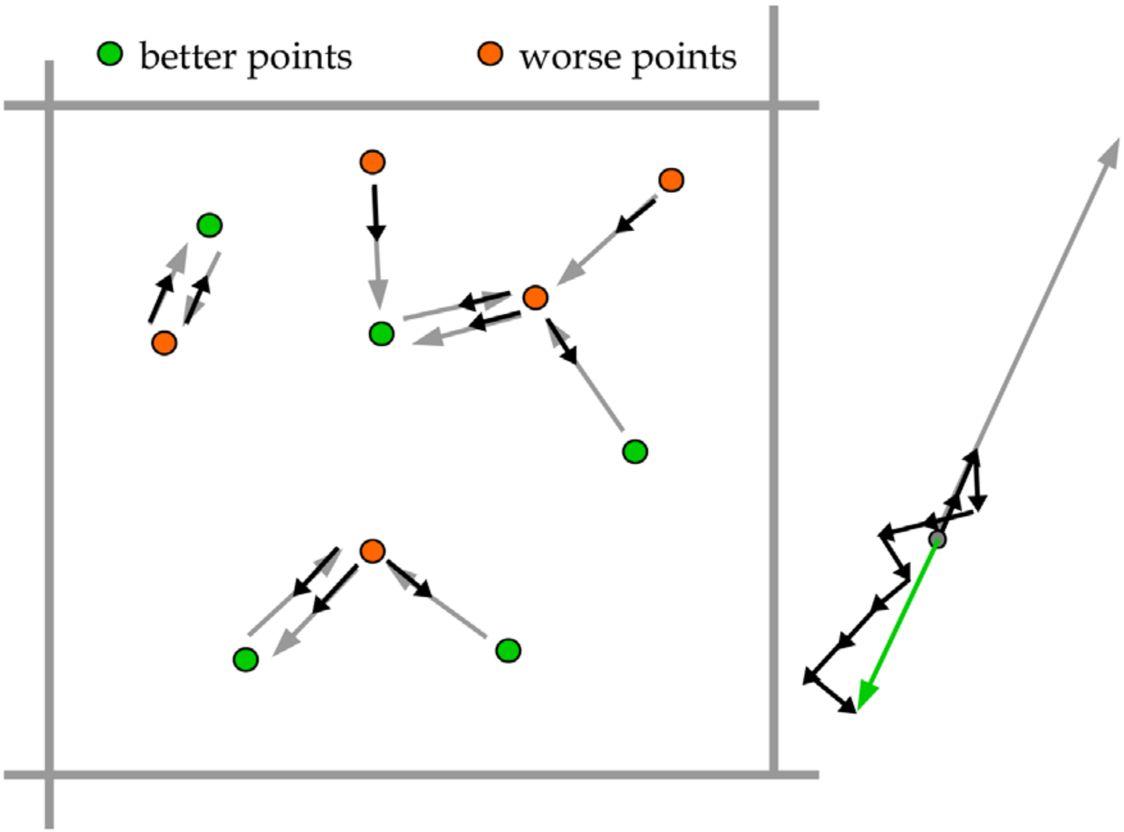
ADDITIONAL FEATURES

- use discretized decision space
- aim at: *global structure*, *homogeneity*, *multi-modality*
- features “measure“:
  - homogeneity of the gradients
  - location of best and worst point within a cell
  - variation in objective values
  - convexity vs. concavity of the landscape

⇒ 12 features (due to different aggregation methods)

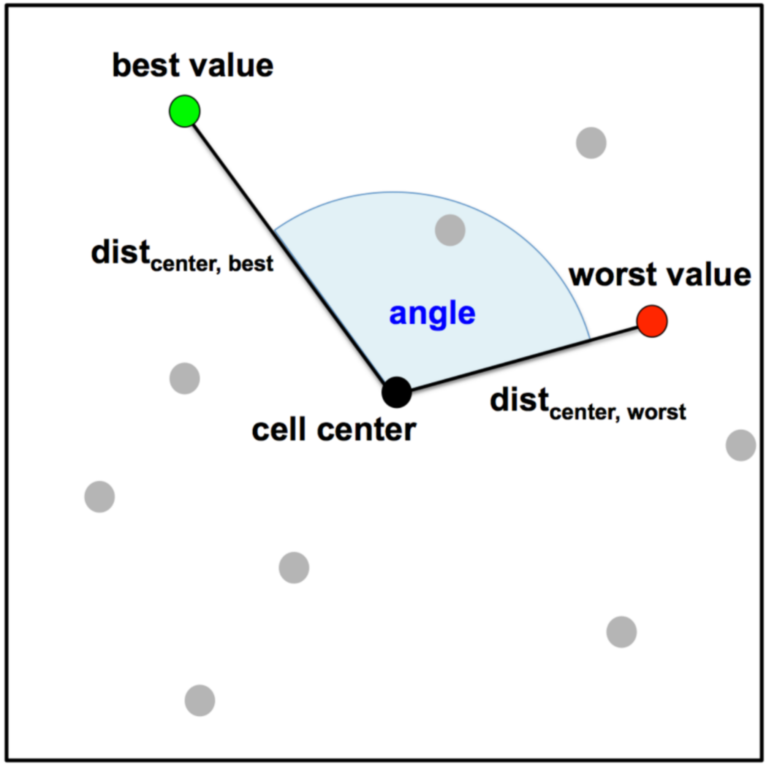
GRADIENT HOMOGENEITY

- sum of directed and normalized (estimated) gradients per cell



LOCATION OF BEST AND WORST VALUES

- angle between best value, cell center and worst value
- distance from center to best / worst point



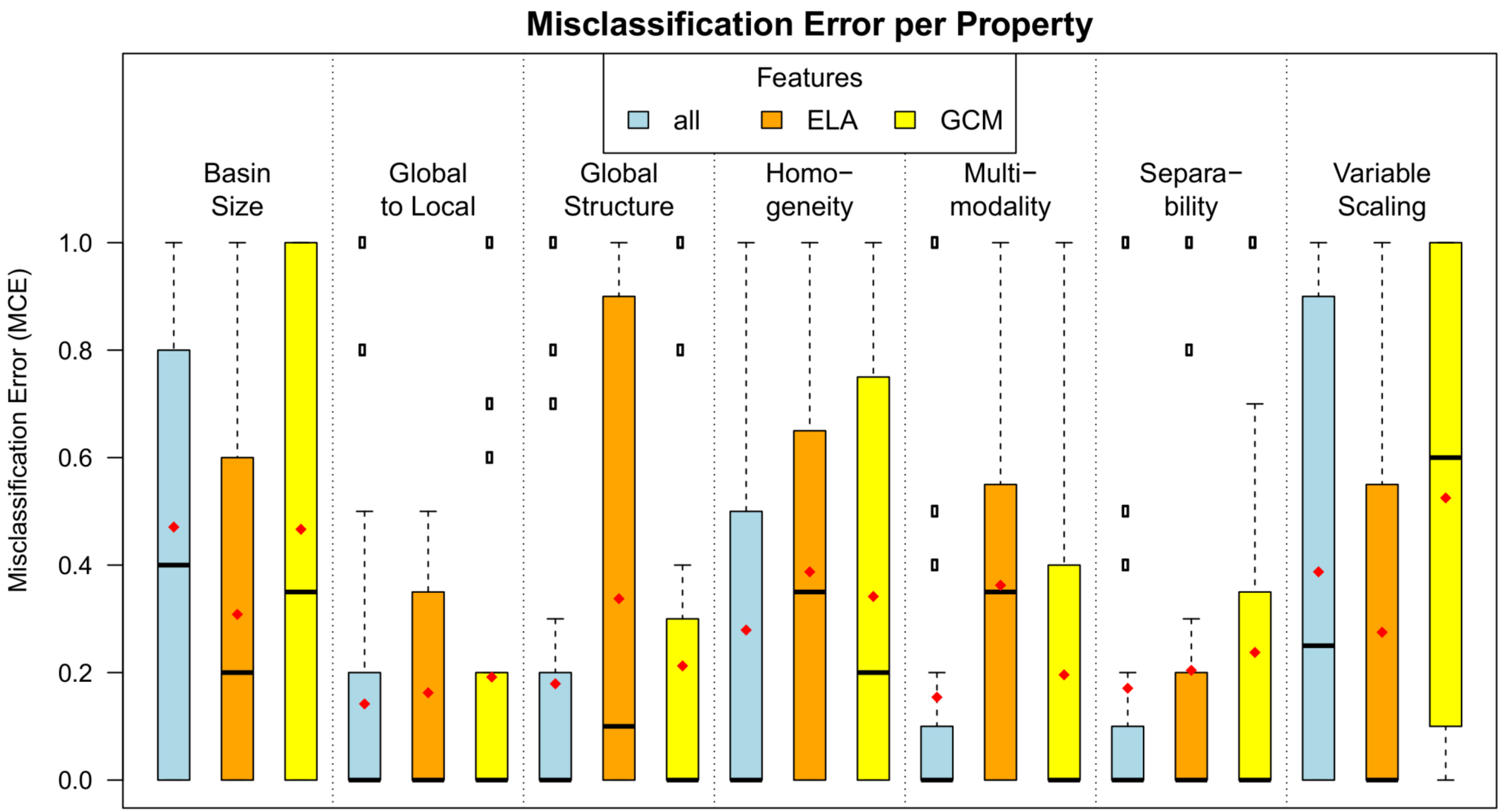
EXPERIMENTS AND RESULTS

- classified seven high-level properties via ELA features,

GCM features, and both

- combination of both worked best for 5 / 7 properties
- especially *global structure*, *homogeneity* and *multi-modality* recognition much better due to new features
- only *basin size* and *variable scaling* not improved
- particularly good: *angle* and *gradient homogeneity* features

EXPERIMENTS AND RESULTS



FURTHER WORK

- extend features for higher-dimensional problems
- employ new features for algorithm selection
- develop new features that also describe the remaining high-level properties
- Efficient feature selection approaches

-> journal paper on ELA methodology

- extend features/algorithm selection for
  - multimodal problems
  - multi-objective problems

ELA FOR MULTIOBJECTIVE PROBLEMS

- Proposal submitted by Trautmann, Grimme, Bischl, Kerschke within

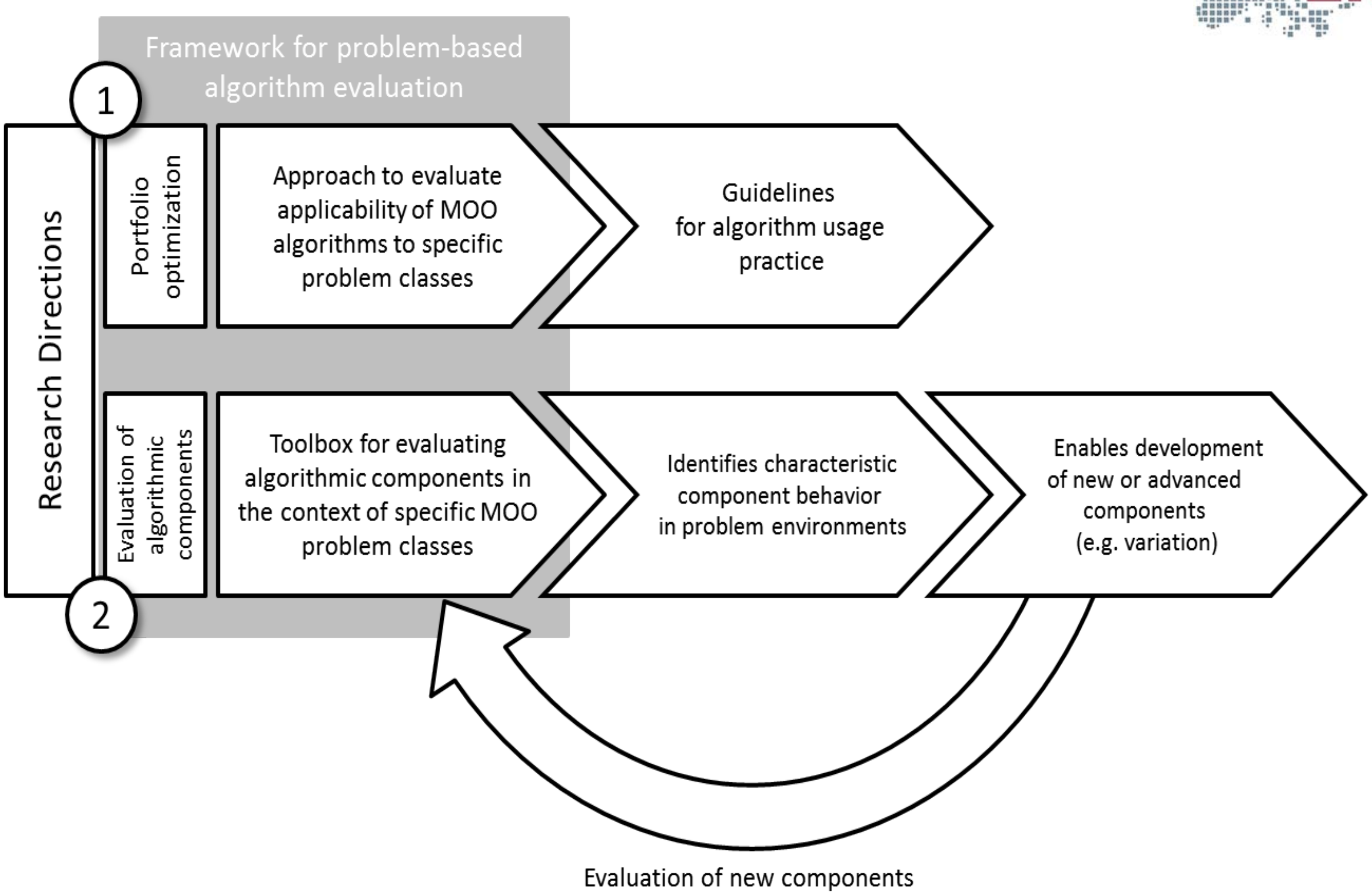
  Group of Eight Australia-Germany (Go88) Joint Research Cooperation Scheme

  together with

  Prof. Dr. Kate Smith Miles
  Monash University, School of Mathematical Science

- Funding Period: 01/2015-12/2016

PROJECT OVERVIEW



PROBLEM-BASED ALGORITHM SELECTION AND DESIGN FOR MULTI-OBJECTIVE OPTIMIZATION

(1) analysis on what makes MOO problems difficult

(2) design of experimental “measures” to numerically characterize MOO problems

(3) identification and visualization of strengths and weaknesses of state-of-the-art MOO algorithms

(4) methodology to assist the algorithm selection on (possibly expensive) real-world problems

(5) methodology to assist the design of tailored algorithms for real-world problems, e.g. manufacturing processes

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TAKE HOME

- ELA APPROACH ALREADY WORKING WELL FOR RESTRICTED SCENARIOS
- CELL MAPPING FEATURES IMPROVE CLASSIFICATION FOR SOME HIGH-LEVEL PROPERTIES
- FUTURE GOALS: LESS FUNCTION EVALUATIONS, BETTER ACCURACY
- ELA SHALL BE APPLIED TO MULTIMODAL / MULTI-OBJECTIVE OPTIMIZATION