CURRENT RESEARCH ON EXPLORATORY LANDSCAPE ANALYSIS

HEIKE TRAUTMANN. MIKE PREUSS.
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

- Convexity
- Search space homogeneity
- y-Distribution
- Plateaus
- Levelset
- Variable scaling
- Meta Model
- Basin size homogeneity
- Local Search
- Global structure
- Global to local optima contrast
- Curvature
- Separability
- Multimodality


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)
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
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.
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

Misclassification Error per Property

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<thead>
<tr>
<th>Features</th>
<th>all</th>
<th>ELA</th>
<th>GCM</th>
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<tbody>
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<td>Basin Size</td>
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<td>Global to Local</td>
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<td>Global Structure</td>
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<td>Variable Scaling</td>
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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/algorith selection for
  - multimodal problems
  - multi-objective problems
ELA FOR MULTIOBJECTIVE PROBLEMS

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

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together with

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

- Funding Period: 01/2015-12/2016
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
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