UNIVERSITY OF APPLIED SCIENCES UPPER AUSTRIA

eurocast 2022

Dynamic Fitness Landscape Analysis

Erik Pitzer, Bernhard Werth and Johannes Karder

22.2.2022

Introduction

- many real-world tasks are actually dynamic problems
- can contain time-linkage
- require more robust algorithms
- could benefit from additional insights in dynamics
- apply and adapt fitness landscape analysis for this purpose

Fitness Landscape Analysis

- problem-independent analysis
- Definition of a Fitness Landscape $\mathcal{F}$
  - Solution Space e.g. S
  - fitness function e.g. $f : S \to \mathbb{R}$
  - neighborhood e.g. $N : S \to \mathrm{P}(S)$ or distance e.g. $d : S \times S \to \mathbb{R}$

FLA Goals

- deep insights into problem class or instance
  - determine inner structure and understanding
  - often complex and time-consuming

- problem class/instance characterization
  - comparison and contrasting with other (known) problem classes and instances
  - often faster and easier heuristic measures

FLA Methods

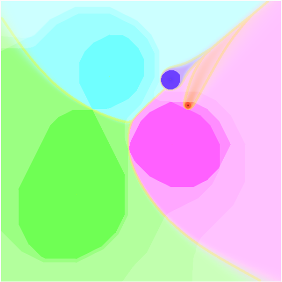
- Sampling-Based Approaches

FLA Methods

- Sampling-Based Approaches
    - random sampling, spaced sampling

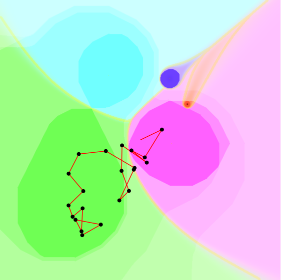
FLA Methods

- Sampling-Based Approaches
  - random sampling, spaced sampling
  - walk-based analysis



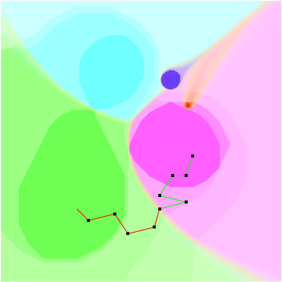
FLA Methods

- Sampling-Based Approaches
  - random sampling, spaced sampling
  - walk-based analysis
    - random walk



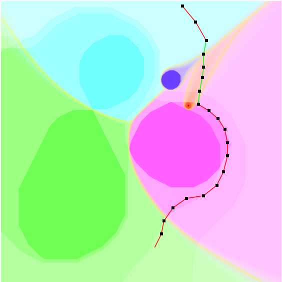
FLA Methods

- Sampling-Based Approaches
  - random sampling, spaced sampling
  - walk-based analysis
    - random walk
    - up-down walk



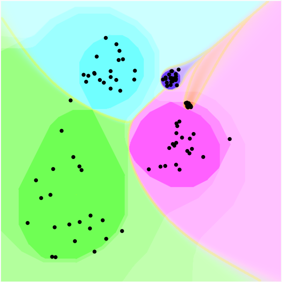
FLA Methods

- Sampling-Based Approaches
  - random sampling, spaced sampling
  - walk-based analysis
    - random walk
    - up-down walk
    - neutral walk



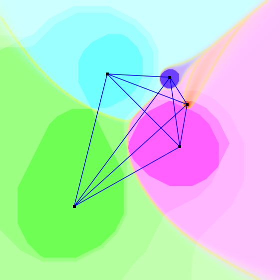
FLA Methods

- Sampling-Based Approaches
  - random sampling, spaced sampling
  - walk-based analysis
    - random walk
    - up-down walk
    - neutral walk
  - optimization-based sampling



FLA Methods

- Sampling-Based Approaches
  - random sampling, spaced sampling
  - walk-based analysis
    - random walk
    - up-down walk
    - neutral walk
  - optimization-based sampling
- Exhaustive Analysis
  - e.g. local optima network analysis



FLA Methods

- Sampling-Based Approaches
  - random sampling, spaced sampling
  - walk-based analysis
    - random walk
    - up-down walk
    - neutral walk
  - optimization-based sampling
- Exhaustive Analysis
  - e.g. local optima network analysis
- (Repeated) Local Analysis
  - on-the-fly near current search algorithm
  - Isotropy estimation

FLA Measures

- Ruggedness
  - Autocorrelation, Correlation Length
  - Information Analysis (Information Content)
- Diversity
- Up/Down Walk Length/Variance
- Neutral Neighbor Fraction
- Neutral Walk Length

Dynamic Optimization Problem

- problem can change during optimization
  - series of different problems over time
  - previous decisions influence the future (time-linkage)
- reuse previous fair solutions (parts)
- Dynamic Vehicle Routing
  - artificial problem with controllable characteristics
  - servicing of power grid facilities, e.g. transformers, generators
  - locations are temporarily active until serviced
  - discrete event simulation
  - hypothetical time between events is used as evaluation budget
  - quality is cumulative “active” time of all cities

Experimental Setup

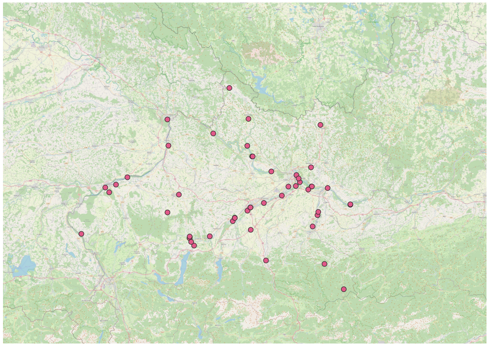
more realistic artificial scenario using geo data

- queried from open street map with overpass API
- largest power station in Upper Austria and around Vienna

```
area[name="Oberösterreich"]->.a;
(
  way(area.a)[power=station];
  way(area.a)[power=substation];
  way(area.a)[power=generator];
  way(area.a)[power=plant];
);
```

Experimental Setup

more realistic artificial scenario using real geo data

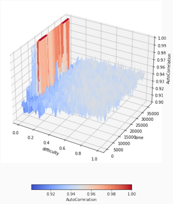


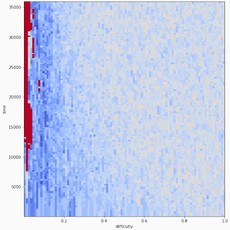
- distance matrix calculated with Open Routing Service
  - local instance ORS (docker)
  - Open Street Map data from geofabrik.de

Experimental Setup and Implementation

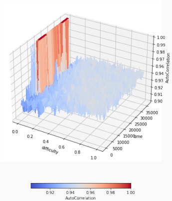
- varying “difficulty” by changing failure probability
- Simulation and Optimization implemented in HeuristicLab
- intermediate problem “snapshots” at every problem change
  - reduced memory consumption with the help of persistent data structures
- FLA on all snapshots
- further analysis using iPython and Pandas

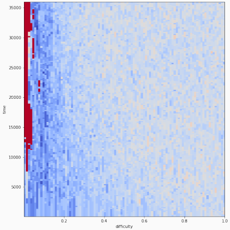
FLA Measures

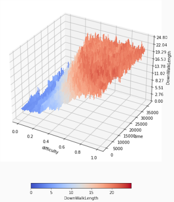


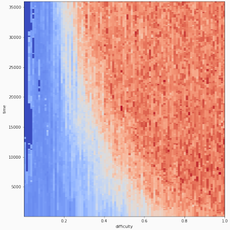


FLA Measures

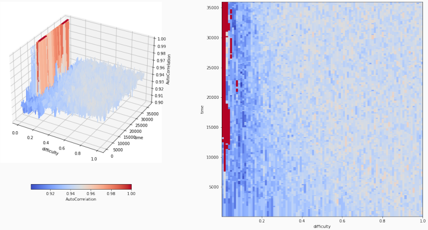


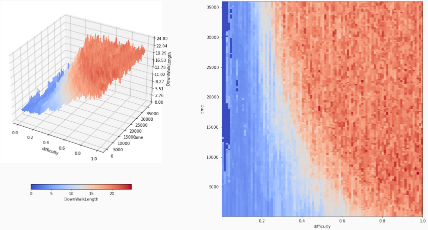


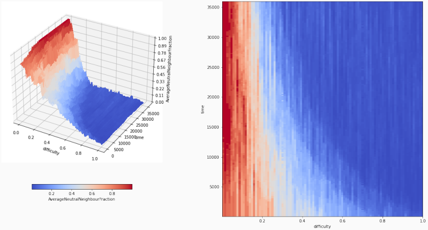




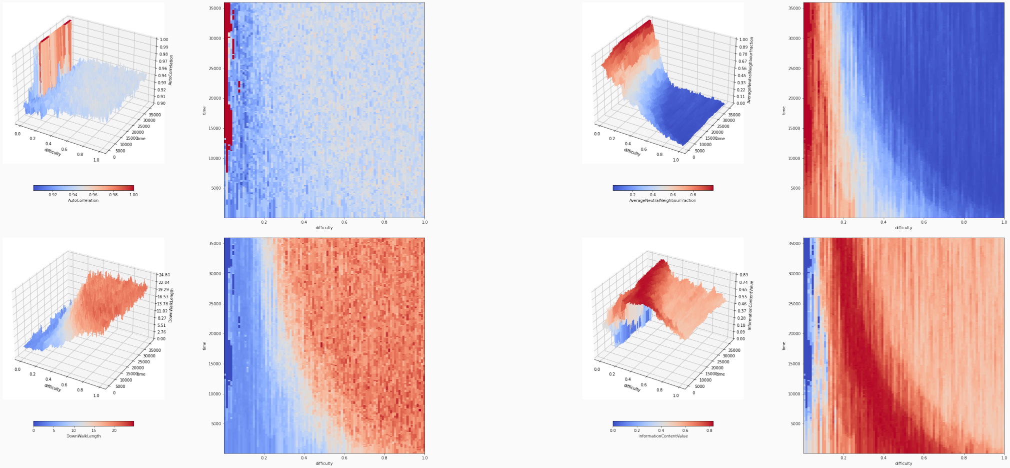
FLA Measures



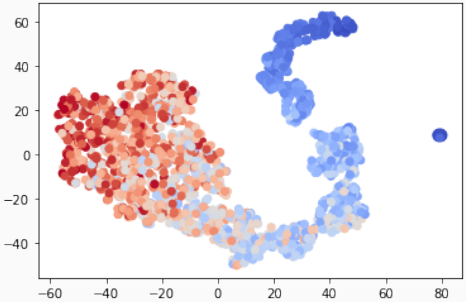


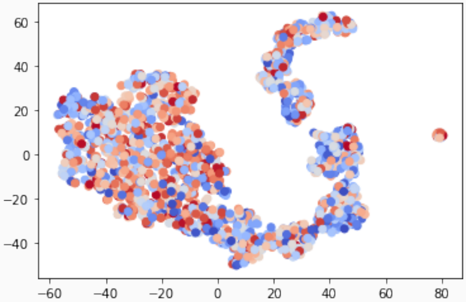


FLA Measures



T-distributed stochastic neighbor embedding





Conclusions & Future Work

- Conclusions
  - fast & simple analysis provides good insights
  - clearly observable boundaries
    - problem is: “too easy” / “interesting” / “too hard”
  - promising foundation for
    - parameter tuning
    - algorithm switching
- Future Work
  - more complex dynamic aspects
    - varying probabilities over time
    - increased coupling of probabilities, e.g. one outage leads to another
  - different optimization algorithms
  - isotropy of FLA measures