HOPL
Heuristic Optimization in Production and Logistics

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http://dev.heuristiclab.com
Research Group HEAL

Research Group

• 5 professors
• 7 PhD students
• Interns, Master and Bachelor students

Research Focus

• Problem modeling
• Process optimization
• Data-based structure identification
• Supply chain and logistics optimization
• Algorithm development and analysis

Scientific Partners

Industry Partners (excerpt)
Metaheuristics

• Intelligent search strategies
• Can be applied to different problems
• Explore interesting regions of the search space (parameter)
• Tradeoff: computation vs. quality
  – Good solutions for very complex problems
• Must be tuned to applications

Challenges

• Choice of appropriate metaheuristics
• Hybridization

Finding Needles in Haystacks
Research Focus

Production planning and Logistics optimization

Modeling and Simulation

Machine Learning

Operations Research

Structure Identification
Data Mining
Regression
Time-Series Classification

Machine Learning

Neural Networks

Statistics
HeuristicLab

Open Source Optimization Framework HeuristicLab
- Developed since 2002
- Basis of many research projects and publications
- 2nd place at Microsoft Innovation Award 2009
- HeuristicLab 3.3 since May 2010 under GNU GPL

Motivation und Goals
- Graphical user interface for interactive development, analysis and application of optimization methods
- Numerous optimization algorithms and optimization problems
- Support for extensive experiments and analysis
- Distribution through parallel execution of algorithms
- Extensibility and flexibility (plug-in architecture)

Cluster at campus Hagenberg
- Research cluster (since March 2006) with 14 cores
- Dell Blade system (since January 2009) with 112 cores
- 200-300 lab computers at campus Hagenberg (since 2011)
- High performance cluster (2016)
Where to get HeuristicLab?

**Download binaries**
- deployed as ZIP archives
- latest stable version 3.3.13
  - released on November 20th, 2015 (Windischgarsten)
- daily trunk builds
- [http://dev.heuristiclab.com/download](http://dev.heuristiclab.com/download)

**Check out sources**
- SVN repository
- HeuristicLab 3.3.13 tag
  - [http://dev.heuristiclab.com/svn/hl/core/tags/3.3.13](http://dev.heuristiclab.com/svn/hl/core/tags/3.3.13)
- current stable branch
  - [http://dev.heuristiclab.com/svn/hl/core/stable](http://dev.heuristiclab.com/svn/hl/core/stable)

**License**
- GNU General Public License (Version 3)

**System requirements**
- Microsoft .NET Framework 4.0 Full Version
- RAM and CPU power
Available Algorithms

Population-based
- CMA-ES
- Evolution Strategy
- Genetic Algorithm
- Offspring Selection Genetic Algorithm
- Island Genetic Algorithm
- Island Offspring Selection Genetic Algorithm
- Parameter-less Population Pyramid (P3)
- SASEGASA
- Relevant Alleles Preserving GA (RAPGA)
- Genetic Programming
- NSGA-II
- Scatter Search
- Particle Swarm Optimization

Trajectory-based
- Local Search
- Tabu Search
- Robust Taboo Search
- Variable Neighborhood Search
- Simulated Annealing

Data Analysis
- Linear Discriminant Analysis
- Linear Regression
- Multinomial Logit Classification
- k-Nearest Neighbor
- k-Means
- Neighbourhood Component Analysis
- Artificial Neural Networks
- Random Forests
- Support Vector Machines
- Gaussian Processes

Additional Algorithms
- User-defined Algorithm
- Performance Benchmarks
- Hungarian Algorithm
- Cross Validation
- LM-BFGS
Available Problems

Combinatorial Problems
- Traveling Salesman
- Vehicle Routing
- Knapsack
- NK[P,Q]
- Job Shop Scheduling
- Linear Assignment
- Quadratic Assignment
- OneMax
- Orienteering
- Deceptive trap
- Deceptive trap step
- HIFF

Genetic Programming Problems
- Symbolic Classification
- Symbolic Regression
- Symbolic Time-Series Prognosis
- Artificial Ant
- Lawn Mower

Additional Problems
- Single-Objective Test Function
- User-defined Problem
- Programmable Problem
- External Evaluation Problem (Anylogic, Scilab, MATLAB)
- Regression, Classification, Clustering
- Trading
- Grammatical Evolution
State of the Art

Typical approach
- Modeling of single tasks
  - Warehouse
  - Production planning
  - Inhouse logistics
  - Transport logistics
- Adaptation of standard problem from the literature (JSSP, CVRP, e.g.)
- Optimization with metaheuristics, exact solvers or hybrid approaches

Recent trends
- Integrated modeling or interrelated tasks
  - Matheuristics which are able to combine two tasks (packing and routing e.g.)
  - Simulation-based optimization

Limitations
- Limitation to just a couple of tasks that can only be described by complex models
- Modeling of specific constraints is difficult
- Limitations in terms of modularity and reusability
Optimization Network

Optimization Results (Returned from Nodes)
- Partial Solutions
- Algorithm Performance
- Problem Characteristics

Orchestration and Analysis

Algorithm and Problem Analysis

Solution Analysis and Integration

Parameter Sets (Sent to Nodes)
- Problem Parameters
- Algorithm Selection
- Parameter Selection
- Runtime Distribution
- Diversification

Optimization Node (e.g. Fault Prediction)

Optimization Node (e.g. Scheduling)

Optimization Node (e.g. Routing)

Optimization Node (e.g. Time Series Modeling)
Fitness Landscape Analysis

- Calculation of features in order to characterize problem instances [PA12, VFM03]
  - ruggedness
  - neutrality
  - misleading
- Visualization with problem instance map
  - projections like PCA, MDS, SOM


Fitness Landscape based Algorithm Prediction

Algorithm performance

- Is random variablee [HS98]
- Probability of obtaining a certain goal w.r.t. effort
- Comparison by mean [AH05]
- Empirical distribution function (ECDF) for visualization

Cluster classification

- k-Means for clustering of mean value (k = 5)
  - Performance classes 1-5
- Additional class if algorithm never reaches the goal (class 6)


Fitness Landscape based Algorithm Prediction

Defines problem instance

Proposes algorithm instance

Proposes budget for effort

Defines target to be achieved

Performance request

mapping (by FLA)

Results

• k-nearest neighbor approach
  – Uses performance data of k nearest problem instances
  – Calculates new ranking
• Leave-One-Out Crossvalidation in order to check approach
• Best proposed algorithm has been compared by ranking
  – 31x algorithm instance from class 1 (best suited)
  – 7x algorithm instance from class 2
  – 5x algorithm instance from class 3-5 (less suited)
  – 4x algorithm instance from class 6 (did not work)
• As a baseline that algorithm instance has been used which is most frequently in class 1
  – 20x class 1
  – 5x class 2
  – 8x class 3-5
  – 14x class 6
Further Details

Talk by A. Beham
Optimization Knowledge Center
A decision support system for heuristic optimization

Thursday, 8:30-10:20, EvoSoft Workshop, Wind River A

http://dev.heuristiclab.com
Interrelated Processes in Production and Logistics

Resource Management

Fault Prediction

Resource Selection

Facility Layout Assignment

Reliabilities

Resources Geometries

Availabilities

Machine Layout

Floor Layout

Manufacturing and Assembly

Demand Time Series Modeling

Production Planning and Scheduling

In-House Transport Routing

Forecast

Prod. Schedule

Pick Sequence

Supplier Management

Supplier Selection

Warehouse Storage Assignment

Material Picking

Deliveries

Parts Make-or-buy

Prod. Schedule Affinities

Storage Locations

Material Handling & In-House Logistics
Example

Workcenter

<table>
<thead>
<tr>
<th>Workcenter</th>
<th>Job1</th>
<th>Job2</th>
<th>Job3</th>
<th>Job4</th>
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</thead>
<tbody>
<tr>
<td>W1</td>
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<td>W4</td>
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</tbody>
</table>

Scheduling

Time

Layout / Routing

Storage
New modeling layer for optimization networks in HeuristicLab

- Optimization networks consist of **nodes**
  - Nodes can include problems and algorithms from HeuristicLab (reusability of standard problems and algorithms)
  - Nodes can be implemented individually (specific problems/algorithms, analysis or visualization components)
  - Nodes can be used as interfaces from/to external applications like simulators (Anylogic), other solvers (CPLEX), or distributed hardware resources (HeuristicLab Hive)
  - Optimization networks are nodes themselves (hierarchical structures)

- Nodes of optimization networks communicate via **ports**
  - Ports have a specific signature (input/output parameters)
  - Nodes send and receive messages via ports
  - Ports support different ways of communication
    - Client/Server
    - Publish/Subscribe
    - both synchronously and asynchronously
Optimization networks GUI

- GUI allows definition of nodes and ports at runtime
- Editor for interactive modeling of optimization networks
- Validation of ports at runtime
- Visual feedback during the run (activity of nodes, qualities)
- Code of ON and nodes can be edited at runtime (in order to be recompiled)
- Code von Optimierungsnetzwerken und Knoten kann in der GUI zur Laufzeit eingesehen, editiert und erneut kompiliert werden

Already implemented examples

- Two flavors of combinations of knapsack and travelling salesman problems
  - Knapsack Constrained Profitable Tour Problem
  - Traveling thief problem
- Combination of feature selection and linear regression
- Real world scenario in a steel production company
Optimization-Networks in HeuristicLab
Optimierungsnetzwerke in HeuristicLab
Optimierungsnetzwerke in HeuristicLab
Optimierungsnetzwerke in HeuristicLab
Optimierungsnetzwerke in HeuristicLab
Real World Optimization Network

- Set building (VNS)
- Stacking (rule, B&B, ...)
- Slab storage (MIP-KB)
- Transport (heuristic)

Data import → Parameter → Process → Action → Recommendations → Set → Stacking → Transport → Slab storage

Ca. 10-20s → <1s-30s
Real-world Optimization Network (Hot Metal Storage)

**Results**

- Recommendation system has been tested in practice a several time
- Results quite good in the meanwhile
  - ~80% approval by human expert
  - ~78% approval by human expert

**Further obvious aspects**

- Planning of warmholding box – highly interdependent with hot metal storage
- Planning of slab adjustment – interrelated with transport
Knowledge Networks
Further Ongoing Activities With Practical Impact

Intra-plant transport logistics
Workshop on Theory and Applications of Metaheuristic Algorithms
Held within the thirteenth International Conference on Computer Aided Systems Theory
eurocast 2017
February 19-24, 2017

http://eurocast2015.fulp.ulpgc.es/

Important Dates:
• Submission Deadline (Extended Abstract): October 31, 2016
• Acceptance Notification: December 1, 2016
• Camera-Ready Paper Deadline: April 30, 2017