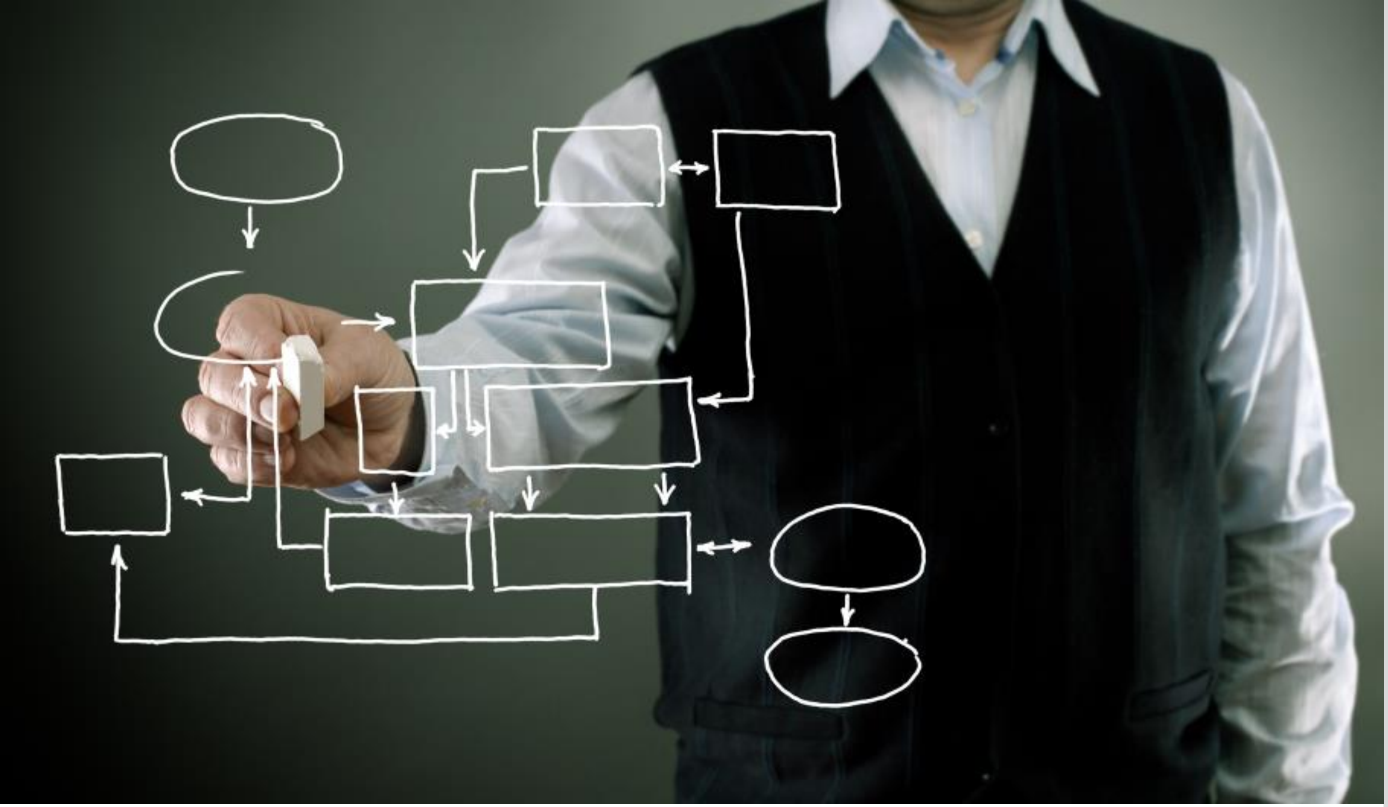

Heuristic Optimization in Production and Logistics

gefördert durch

FFG
Österreichische Forschungsförderungsgesellschaft

LAND OBERÖSTERREICH

HOPL

Heuristic Optimization in Production and Logistics

FH OBERÖSTERREICH

universität wien

JKU JOHANNES KEPLER UNIVERSITÄT LINZ

PROFACTOR

v research

RISC Software GmbH

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Web:
http://heal.heuristiclab.com
http://dev.heuristiclab.com

Research Group *HEAL*

Heuristic Optimization in Production and Logistics

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

Industry Partners (excerpt)

rosenbauer, carvatech, TRUMPF, SIEMENS, voestalpine, AKH Linz, T.I.G., A1, GUNYTRONIC

Scientific Partners

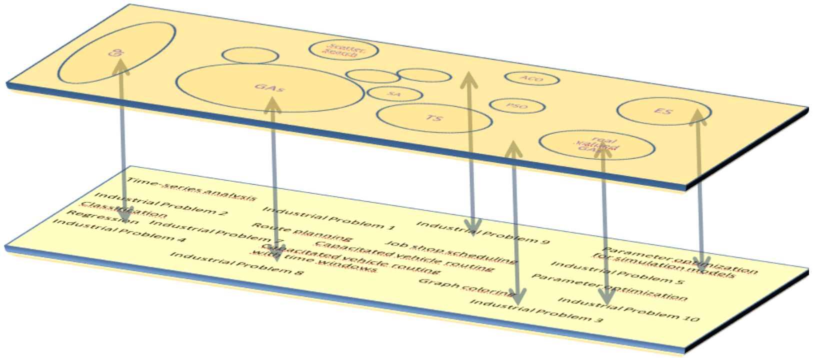
JKU Johannes Kepler Universität Linz, ADS Algorithms and Data Structures Group, Budapest Tech, RTU, PROFACTOR, KIT Karlsruhe Institute of Technology, Universidad de Málaga, Università della Calabria, Logistikum Steyr, M·A·S

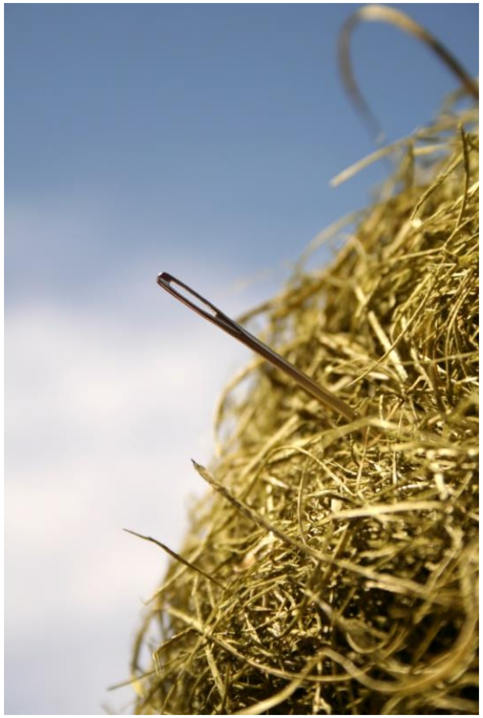
Metaheuristics

- 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

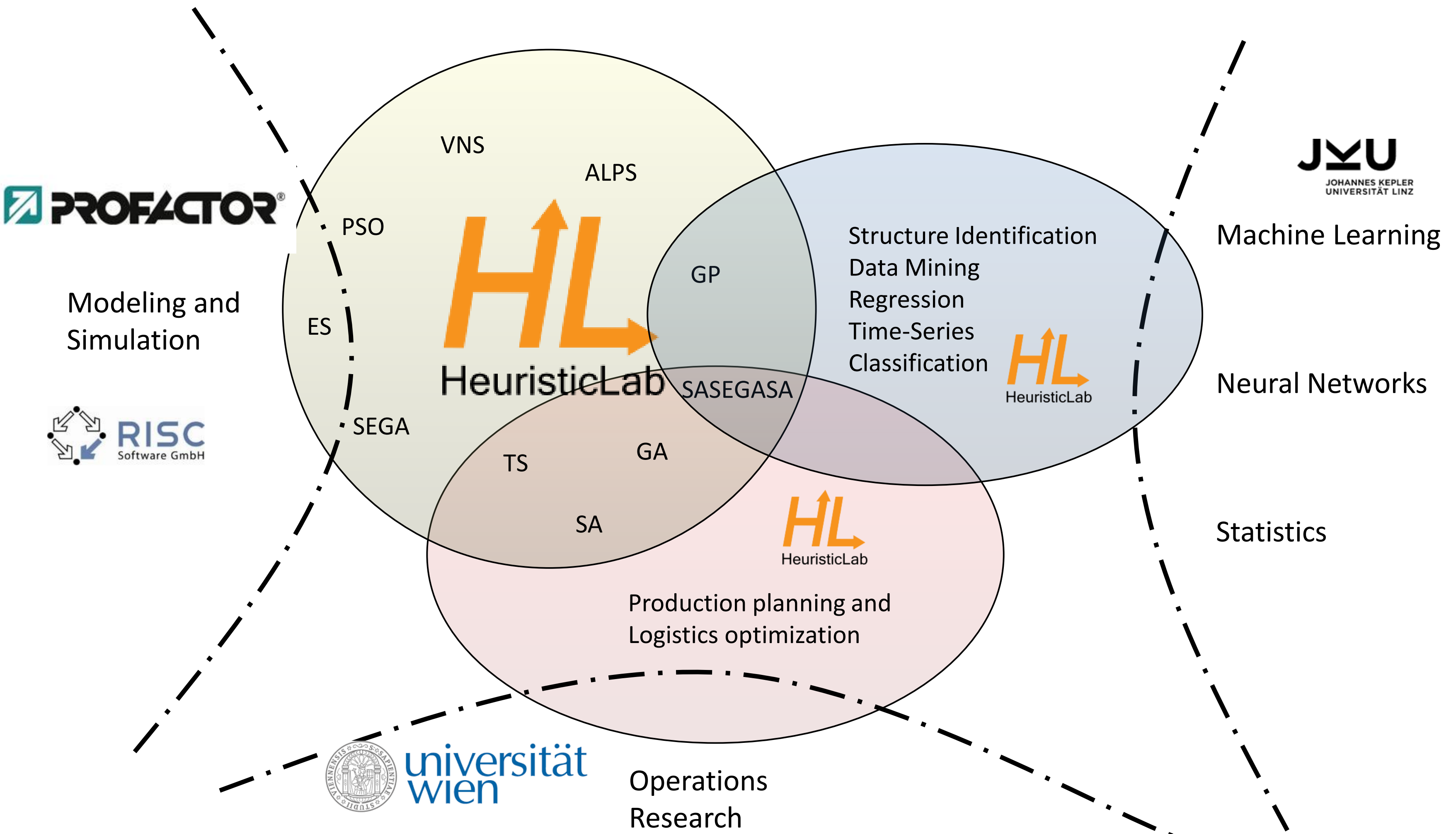




Finding Needles in Haystacks

Research Focus

Heuristic Optimization in Production and Logistics



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

HeuristicLab

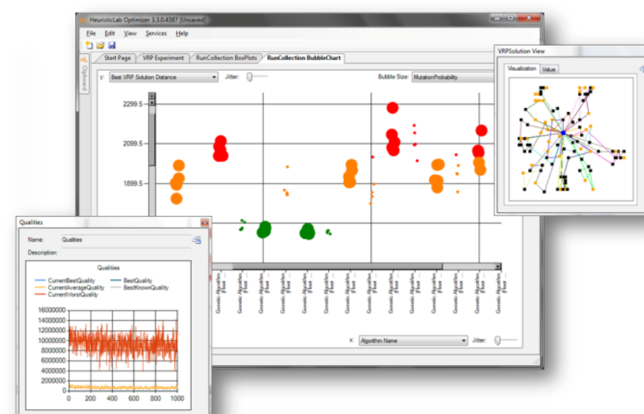
http://dev.heuristiclab.com

Motivation und Goals

- Graphical user interface for interactive development, analysis and application of optimizations 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

Check out sources

- SVN repository
- HeuristicLab 3.3.13 tag
  - http://dev.heuristiclab.com/svn/hl/core/tags/3.3.13
- current stable branch
  - 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

Heuristic Optimization in Production and Logistics

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

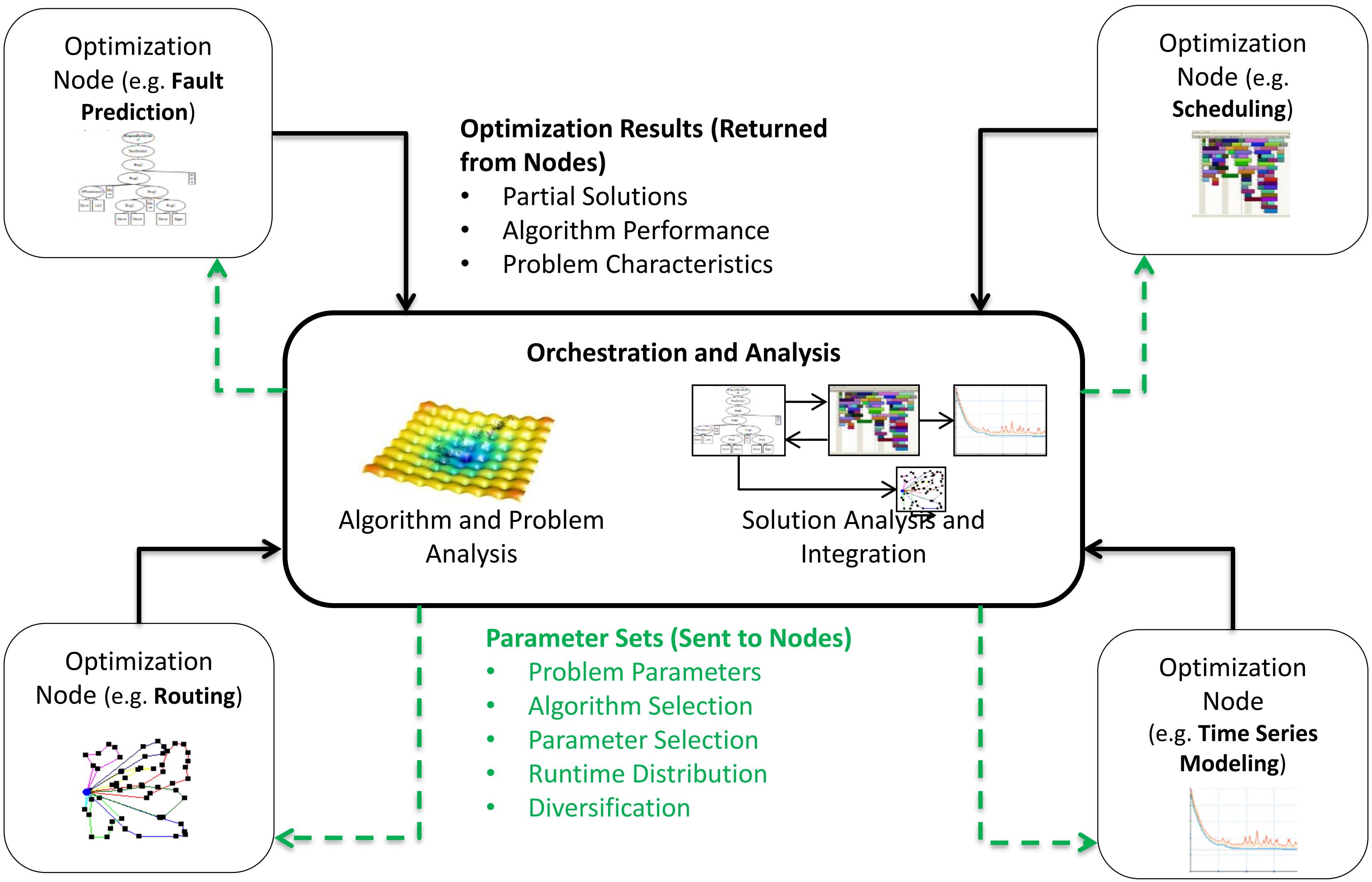
Recent trends

- 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



Fitness Landscape based Algorithm Prediction

Heuristic Optimization in Production and Logistics

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

[PA12] Pitzer, E. and Affenzeller, M., 2012. A comprehensive survey on fitness landscape analysis. In Recent Advances in Intelligent Engineering Systems (pp. 161-191). Springer Berlin Heidelberg.

[VFM03] Vassilev, V. K., Fogarty, T. C., and Miller, J. F. 2003. Smoothness, Ruggedness and Neutrality of Fitness Landscapes: From Theory to Application. In: Ghosh, A., Tsutsui, S. (eds.) Advances in Evolutionary Computing: Theory and Applications, pp. 3-44. Springer-Verlag New York, Inc.

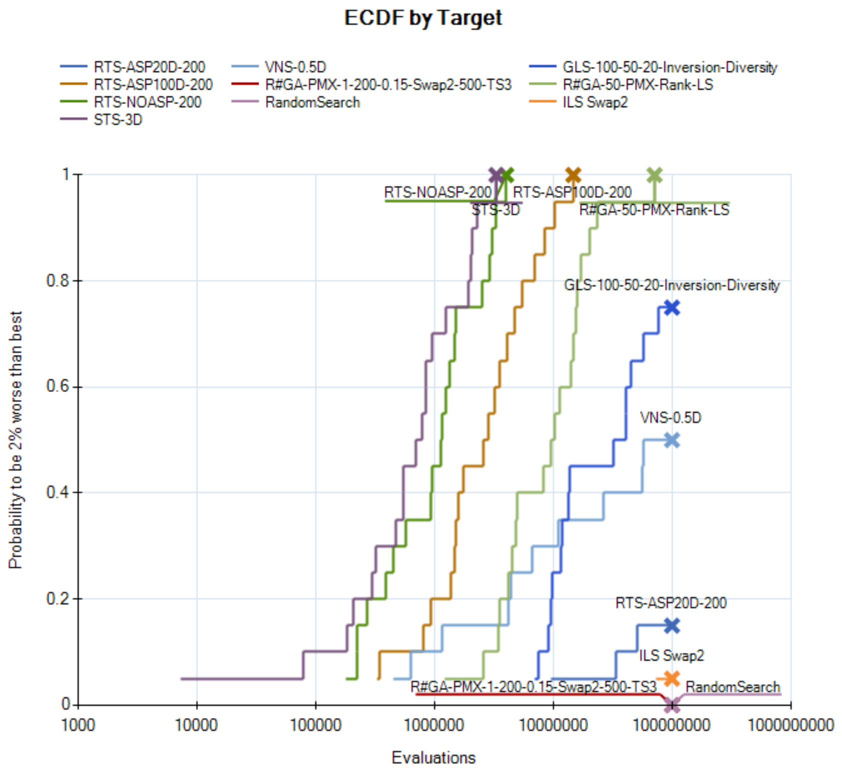
Fitness Landscape based Algorithm Prediction

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 vizualization

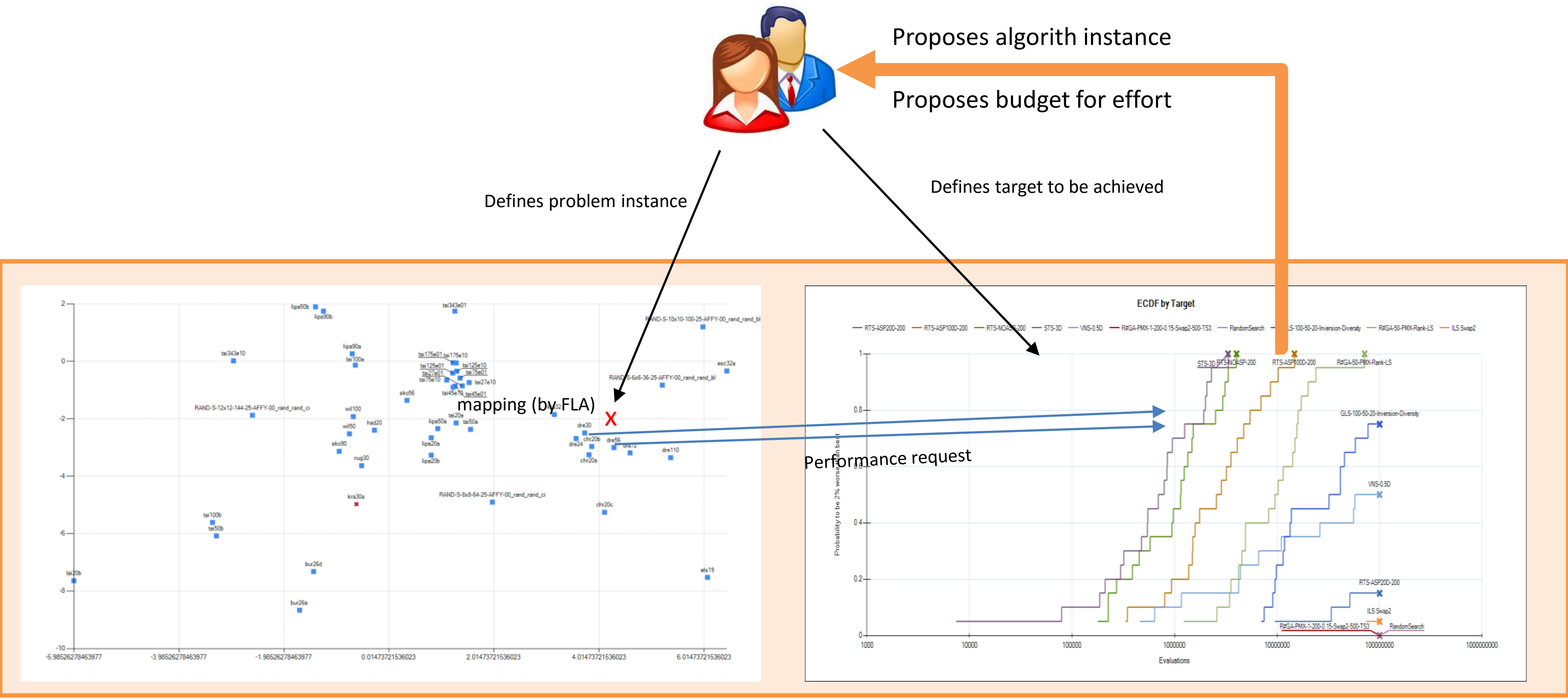
Cluster classification

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



[HS98] Hoos, H. H. & Stützle, T. Evaluating Las Vegas Algorithms - Pitfalls and Remedies. *Proceedings of the Fourteenth Conference on Uncertainty in Artificial Intelligence (UAI-98), Morgan Kaufmann,* 1998, pp. 238-245.
[AH05] Auger, A. & Hansen, N. Performance evaluation of an advanced local search evolutionary algorithm. *Proceedings of the 2005 IEEE Congress on Evolutionary Computation (CEC),* 2005, *2*, pp. 1777-1784.

Fitness Landscape based Algorithm Prediction



[BWA16] Beham, A., Wagner, S., Affenzeller, M. 2016. Optimization Knowledge Center – A Decision Support System for Heuristic Optimization. In Proceedings of the Companion Publication of the 2016 Annual Conference on Genetic and Evolutionary Computation (GECCO'16), p. 6 (accepted)

Fitness Landscape based Algorithm Prediction

Heuristic Optimization in Production and Logistics

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

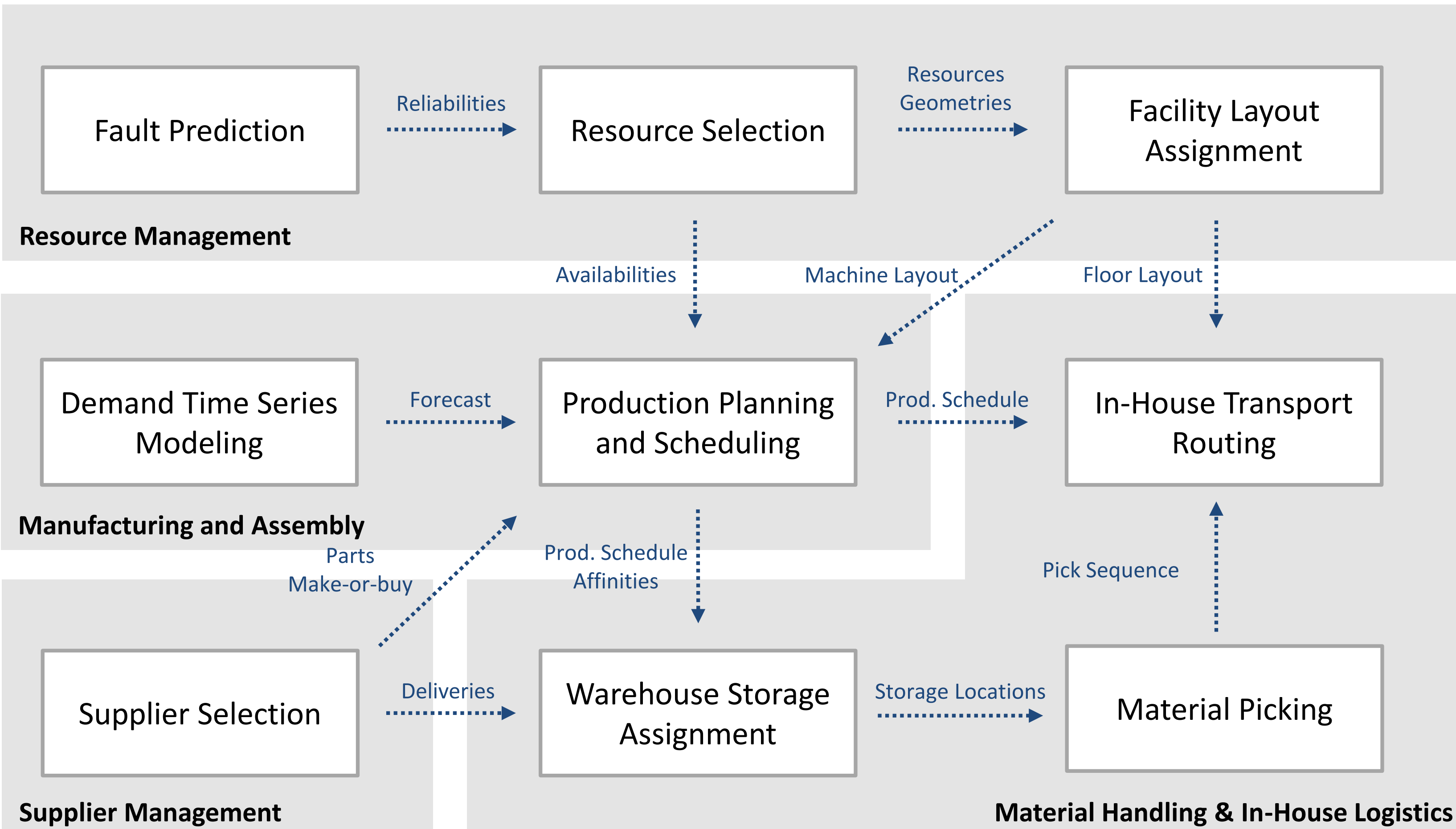
Further Details

- Talk by A. Beham
  Optimization Knowledge Center
  A decision support system for heuristic optimization
- Thursday, 8:30-10:20, EvoSoft Workshop, Wind River A

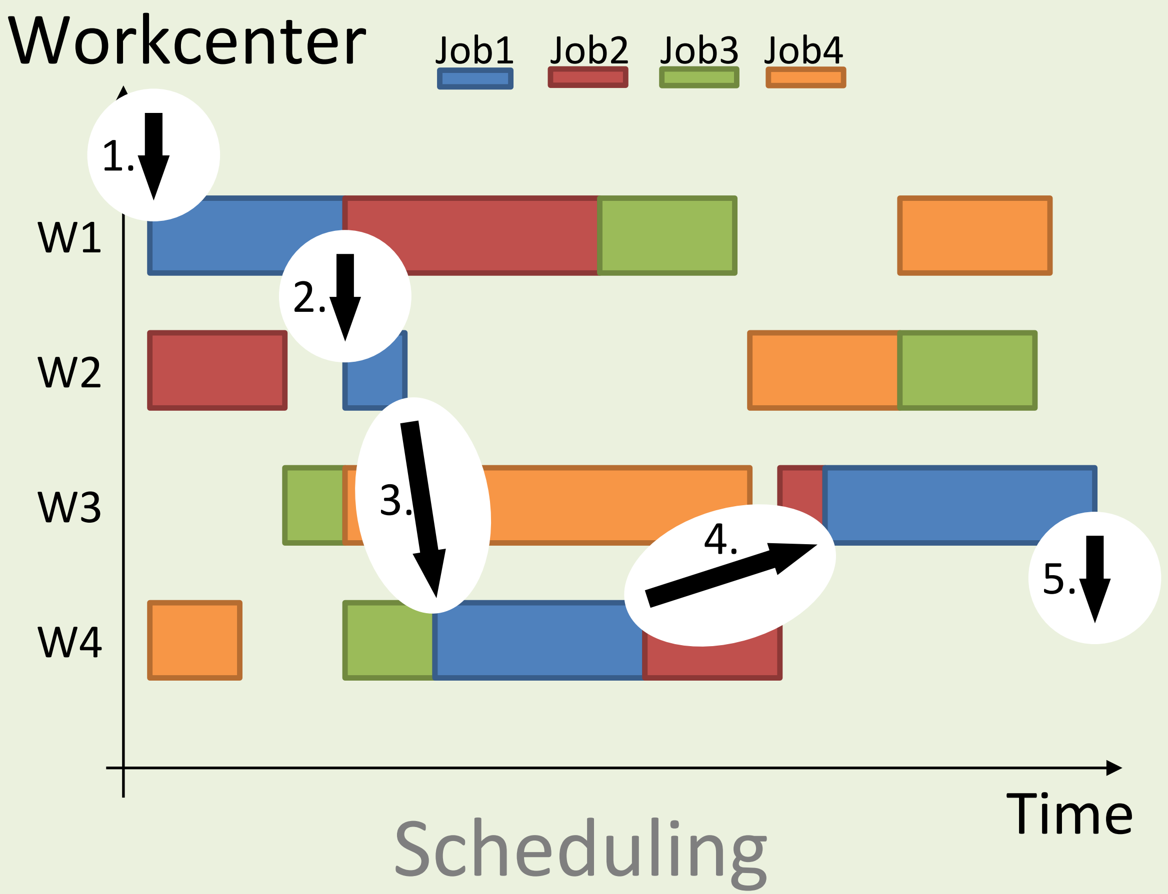
HeuristicLab
A Paradigm-Independent and Extensible
Environment for Heuristic Optimization

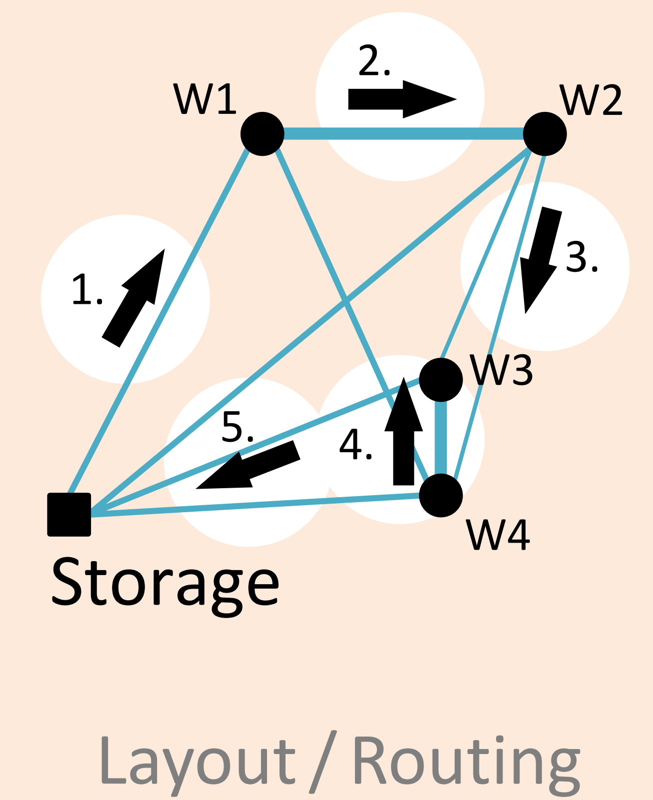
http://dev.heuristiclab.com

Interrelated Processes in Production and Logistics



Example


Workcenter
Job1
Job2
Job3
Job4
W1
W2
W3
W4
1.
2.
3.
4.
5.
Time
Scheduling


W1
W2
W3
W4
Storage
1.
2.
3.
4.
5.
Layout / Routing

Optimization Networks in HeuristicLab

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 vizualiztion components)
  - Nodes can be used as interfaces from/to external applications like simulators (Anylogic), other solvers (CPLEX), or distributed hardware ressources (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

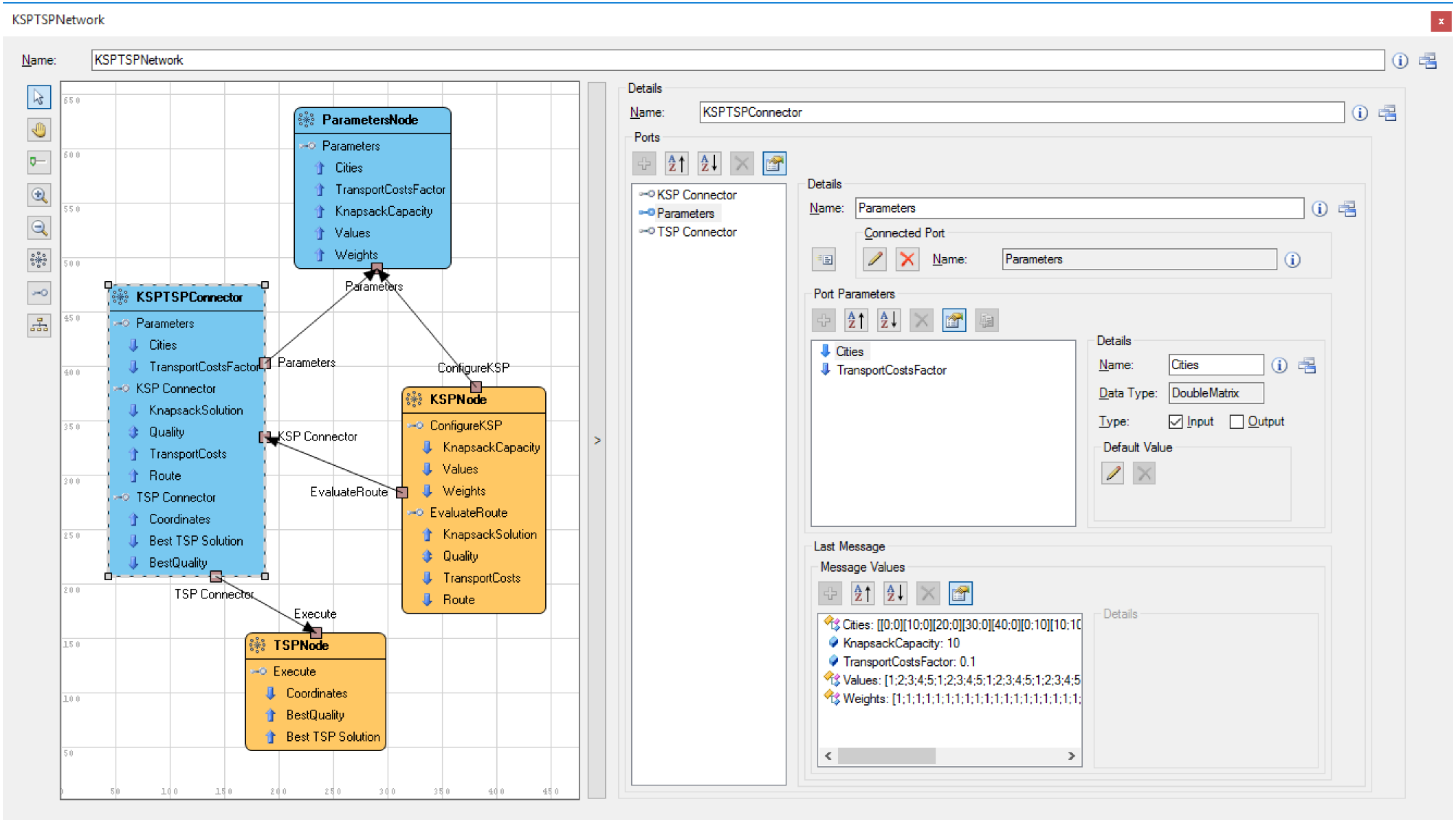
Optimization networks GUI

- 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

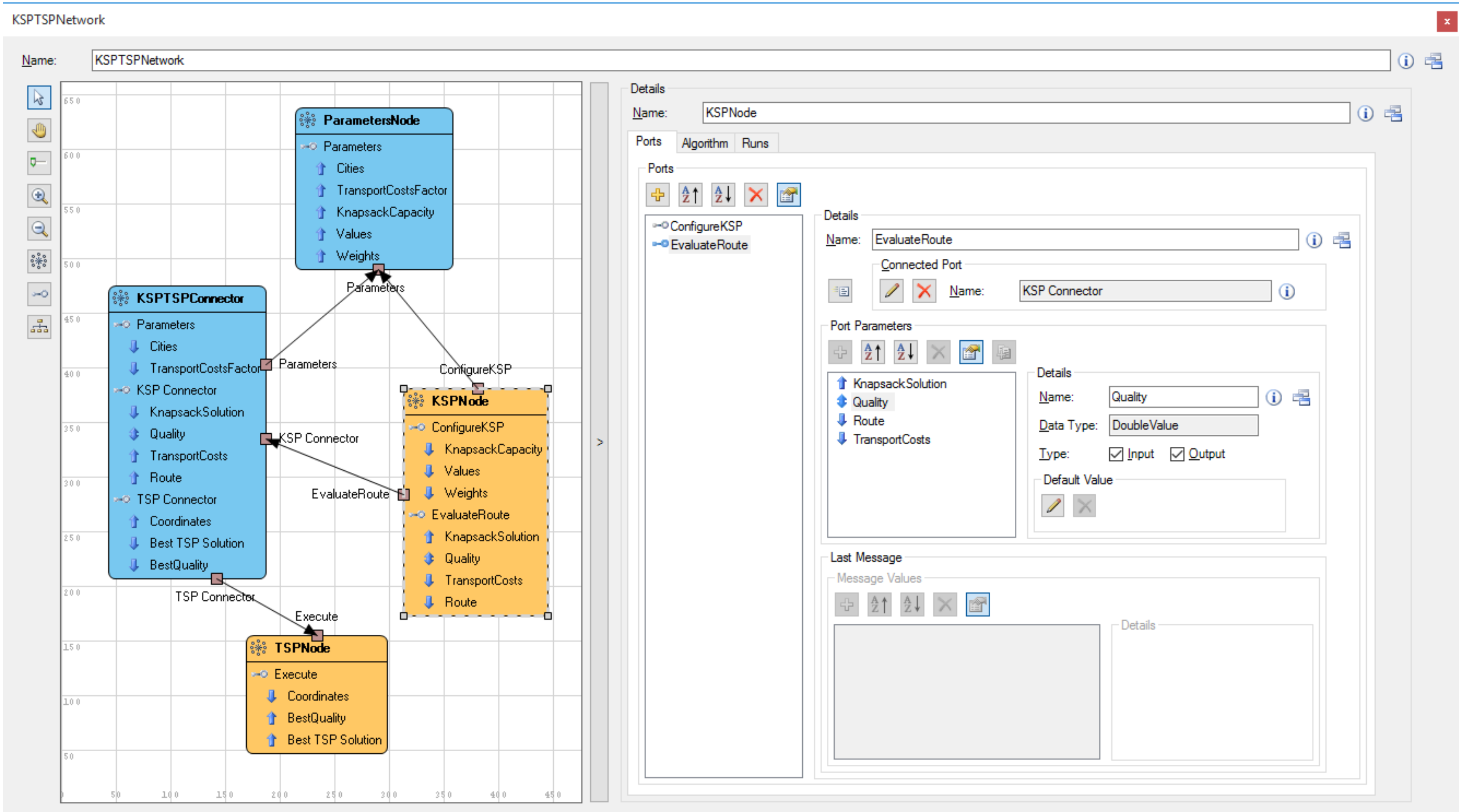
Already implemented examples

- 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

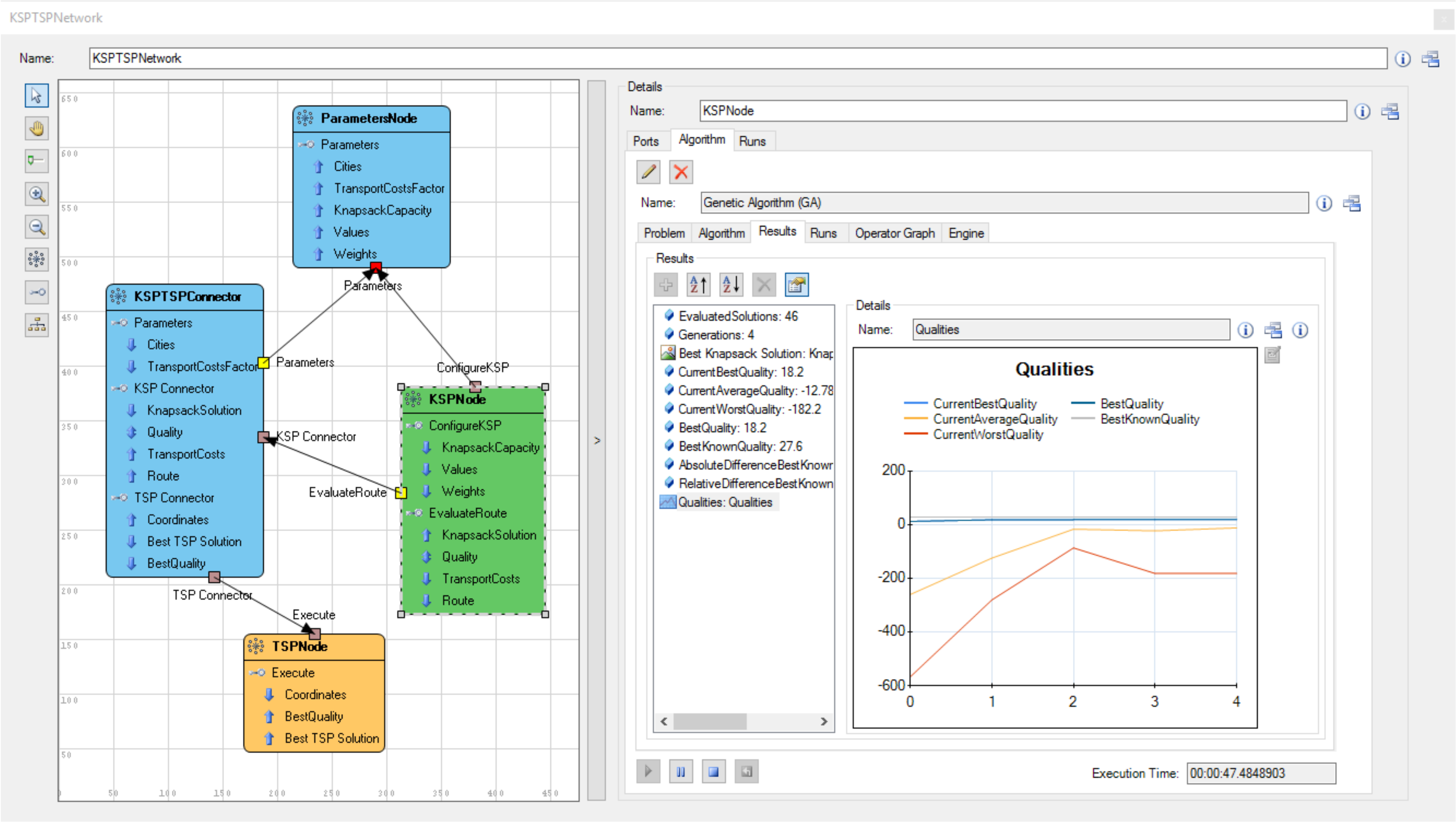
Optimization-Networks in HeuristicLab



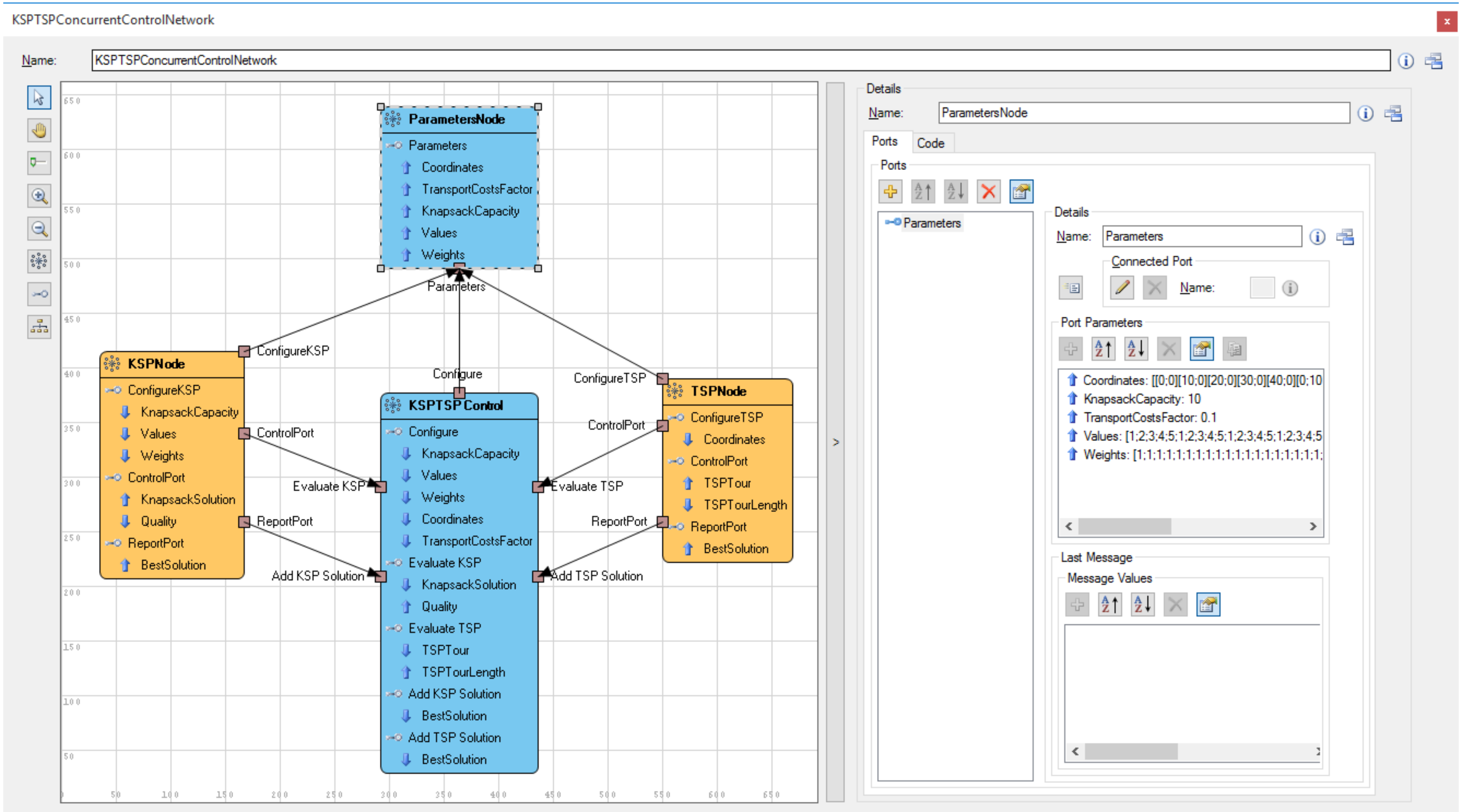
Optimierungsnetzwerke in HeuristicLab



Optimierungsnetzwerke in HeuristicLab

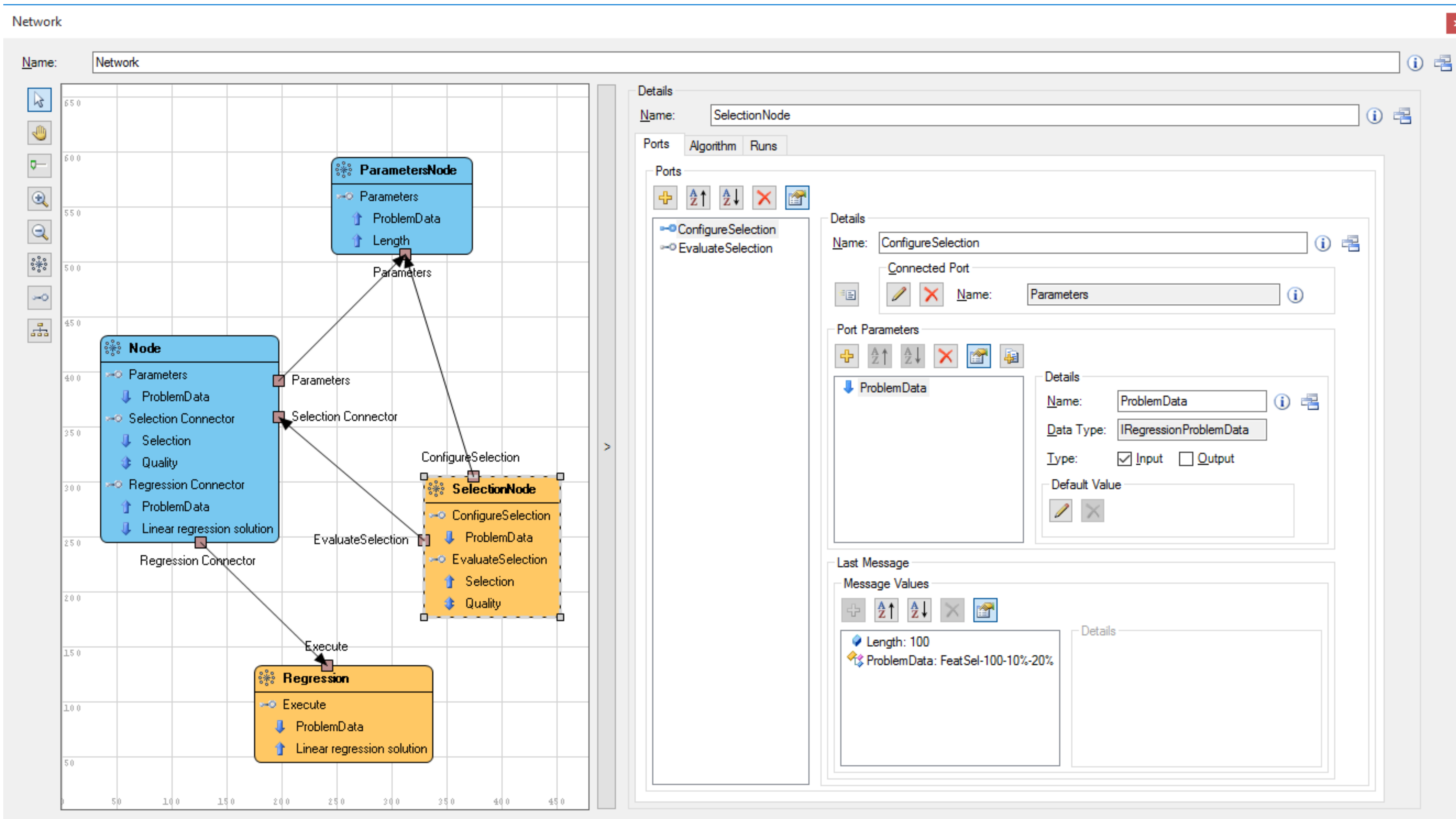


Optimierungsnetzwerke in HeuristicLab

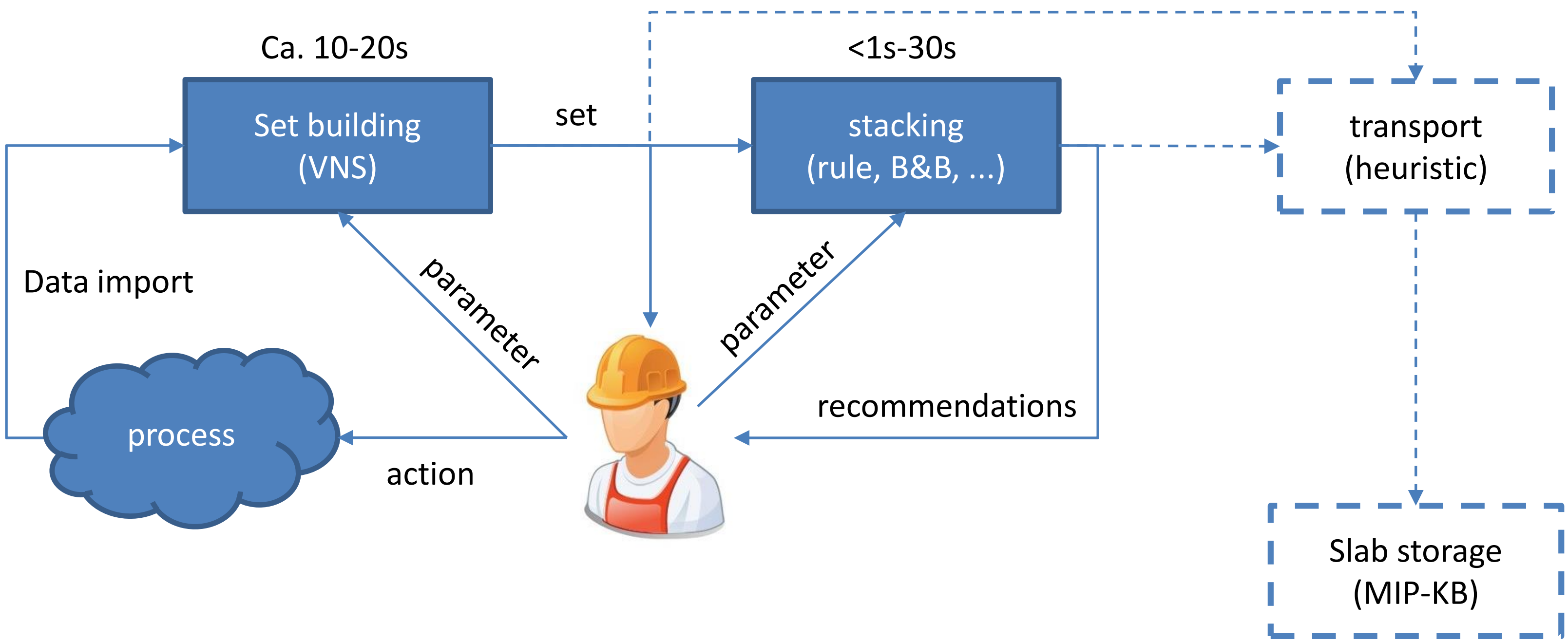


Optimierungsnetzwerke in HeuristicLab

Heuristic Optimization in Production and Logistics



Real World Optimization Network



Real-world Optimization Network (Hot Metal Storage)

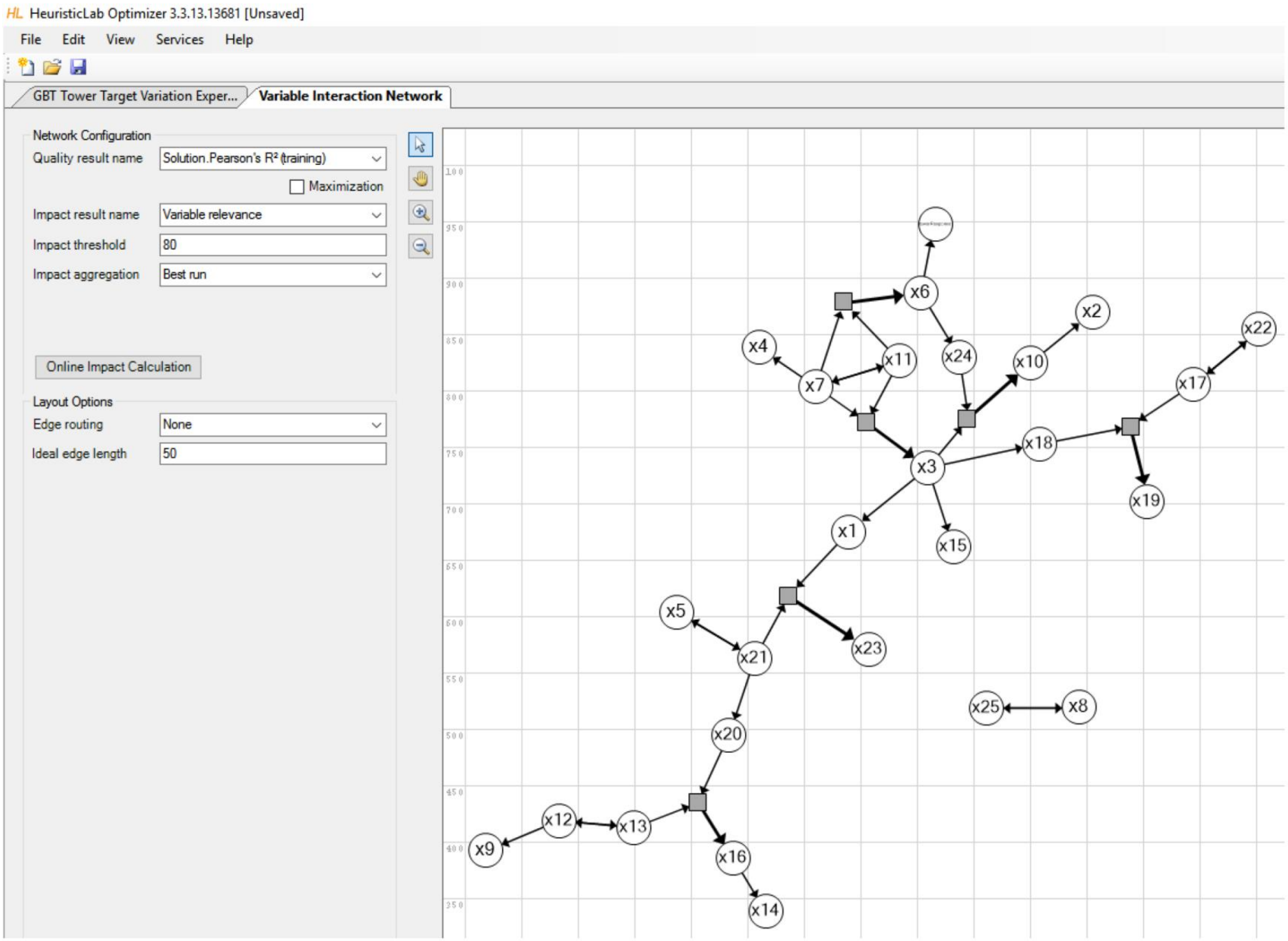
Results

- Recommendation system has been tested in practice a several time
- Results quite good in the meanwhile
- 21. April 2016
  - **~80% approval by human expert**
- 18. Mai 2016
  - **~78% approval by human expert**

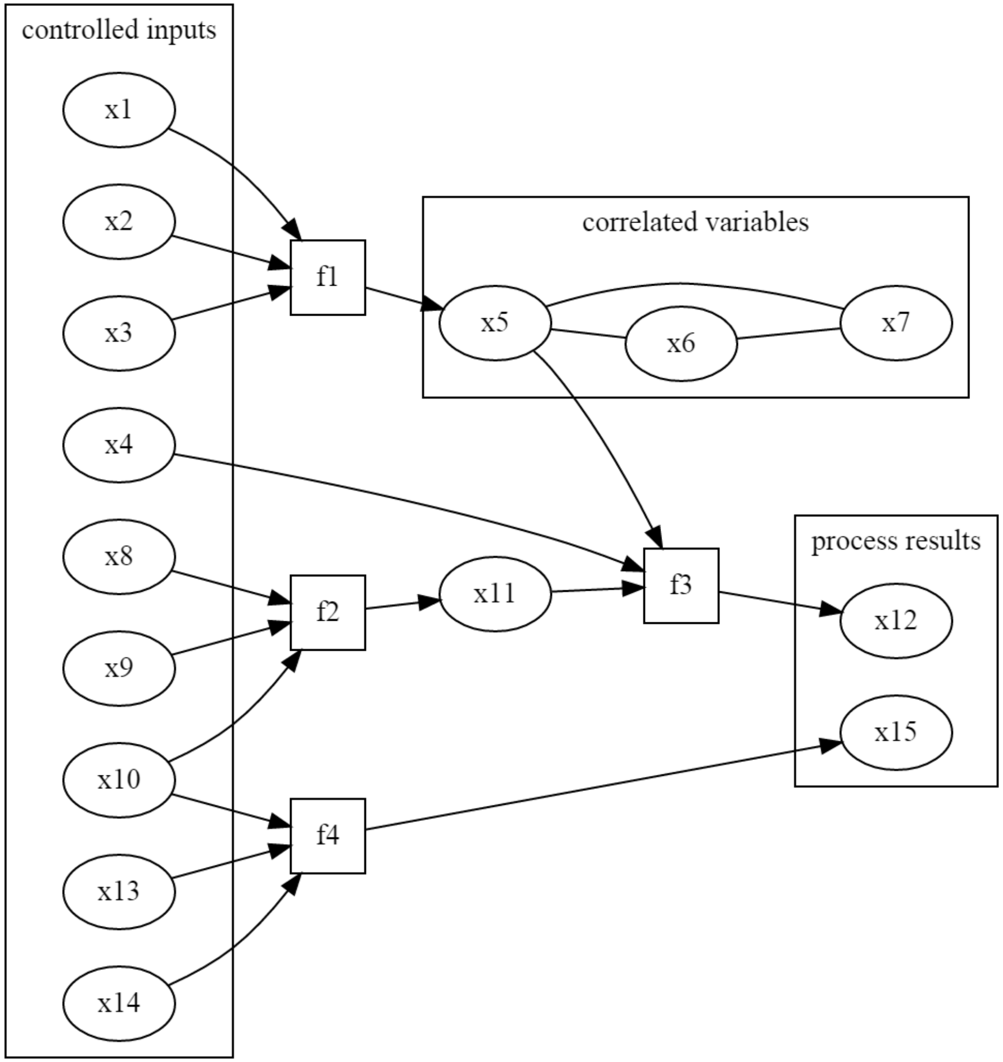
Further obvious aspects

- Planning of warmholding box – highly interdependent with hot metal storage
- Planning of slab adjustment – interrelated with transport

Knowledge Networks



Knowledge Networks



Further Ongoing Activities With Practical Impact

Heuristic Optimization in Production and Logistics

- 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