



HeuristicLab
A Paradigm-Independent and Extensible
Environment for Heuristic Optimization

Algorithm and Experiment Design with HeuristicLab

An Open Source Optimization Environment for
Research and Education

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Agenda

- Objectives of the Tutorial
- Introduction
- Where to get HeuristicLab?
- Plugin Infrastructure
- Graphical User Interface
- Available Algorithms & Problems
- **Demonstration Part I: Working with HeuristicLab**
- **Demonstration Part II: Data-based Modeling**
- Some Additional Features
- Planned Features
- Team
- Suggested Readings
- Bibliography
- Questions & Answers

HeuristicLab Tutorial

<http://dev.heuristiclab.com>

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Instructor Biographies



- **Stefan Wagner**
 - Full professor for complex software systems (since 2009)
 - University of Applied Sciences Upper Austria
 - Co-founder of the HEAL research group
 - Project manager and chief architect of HeuristicLab
 - PhD in technical sciences (2009)
 - Johannes Kepler University Linz, Austria
 - Associate professor (2005 – 2009)
 - University of Applied Sciences Upper Austria
 - <http://heal.heuristiclab.com/team/wagner>



- **Gabriel Kronberger**
 - Full professor for business intelligence (since 2011)
 - University of Applied Sciences Upper Austria
 - Member of the HEAL research group
 - Architect of HeuristicLab
 - PhD in technical sciences (2010)
 - Johannes Kepler University Linz, Austria
 - Research assistant (2005 – 2011)
 - University of Applied Sciences Upper Austria
 - <http://heal.heuristiclab.com/team/kronberger>



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Objectives of the Tutorial



- Introduce general motivation and design principles of HeuristicLab
- Show where to get HeuristicLab
- Explain basic GUI usability concepts
- Demonstrate basic features
- Demonstrate editing and analysis of optimization experiments
- Demonstrate custom algorithms and graphical algorithm designer
- Demonstrate data-based modeling features
- Outline some additional features

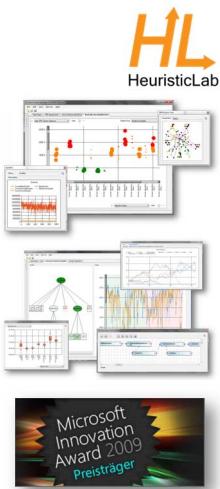
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Introduction

- Motivation and Goals
 - graphical user interface
 - paradigm independence
 - multiple algorithms and problems
 - large scale experiments and analyses
 - parallelization
 - extensibility, flexibility and reusability
 - visual and interactive algorithm development
 - multiple layers of abstraction
- Facts
 - development of HeuristicLab started in 2002
 - based on Microsoft .NET and C#
 - used in research and education
 - second place at the *Microsoft Innovation Award 2009*
 - open source (GNU General Public License)
 - version 3.0 released on May 18th, 2010
 - latest version 3.3.6 released on January 3rd, 2012



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Where to get HeuristicLab?

- Download binaries
 - deployed as ZIP archives
 - latest stable version 3.3.6
 - released on January 3rd, 2012
 - daily trunk builds
 - <http://dev.heuristiclab.com/download>
- Check out sources
 - SVN repository
 - HeuristicLab 3.3.6 tag
 - <http://dev.heuristiclab.com/svn/hl/core/tags/3.3.6>
 - current development trunk
 - <http://dev.heuristiclab.com/svn/hl/core/trunk>
- License
 - GNU General Public License (Version 3)
- System requirements
 - Microsoft .NET Framework 4.0 Full Version
 - enough RAM and CPU power ;-)



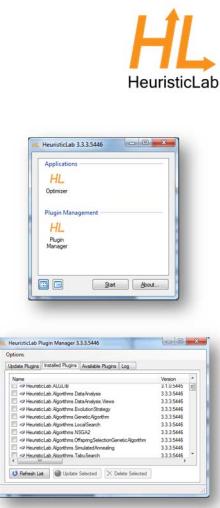
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Plugin Infrastructure

- HeuristicLab consists of many assemblies
 - 94 plugins in HeuristicLab 3.3.6
 - plugins can be loaded or unloaded at runtime
 - plugins can be updated via internet
 - application plugins provide GUI frontends
- Extensibility
 - developing and deploying new plugins is easy
 - dependencies are explicitly defined, automatically checked and resolved
 - automatic discovery of interface implementations (service locator pattern)
- Plugin Manager
 - GUI to check, install, update or delete plugins

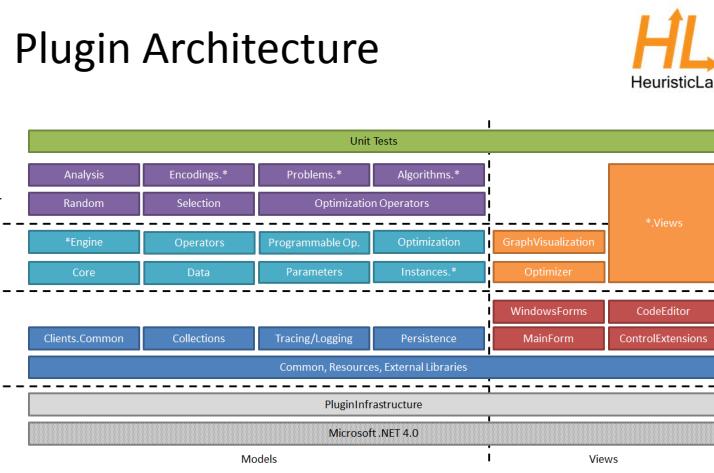


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Plugin Architecture



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Graphical User Interface



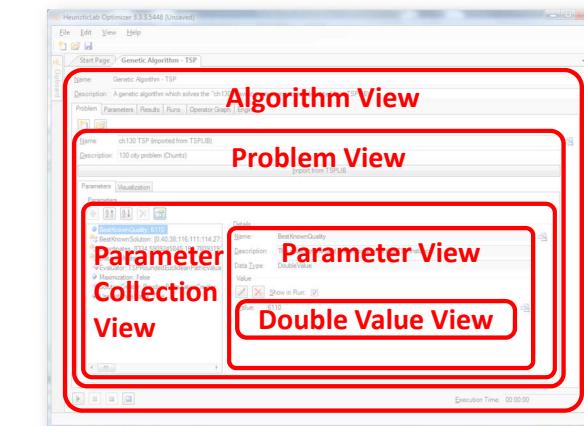
- HeuristicLab GUI is made up of views
 - views are visual representations of content objects
 - views are composed in the same way as their content
 - views and content objects are loosely coupled
 - multiple different views may exist for the same content
- Drag & Drop
 - views support drag & drop operations
 - content objects can be copied or moved (shift key)
 - enabled for collection items and content objects

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Graphical User Interface



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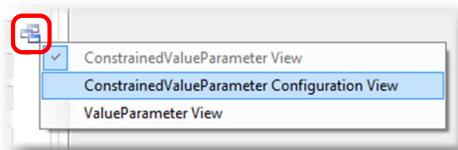
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Graphical User Interface



- ViewHost
 - control which hosts views
 - right-click on windows icon to switch views
 - double-click on windows icon to open another view
 - drag & drop windows icon to copy contents



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Available Algorithms & Problems



Algorithms

- Evolution Strategy
- Genetic Algorithm
- Genetic Programming
- Island Genetic Algorithm
- Island Offspring Selection Genetic Algorithm
- Local Search
- NSGA-II
- Offspring Selection Genetic Algorithm
- Particle Swarm Optimization
- Robust Taboo Search
- SASEGASA
- Simulated Annealing
- Tabu Search
- User-defined Algorithm
- Variable Neighborhood Search
- Performance Benchmarks
- Cross Validation
- k-Means
- Linear Discriminant Analysis
- Linear Regression
- Multinomial Logit Classification
- Nearest Neighbor Regression and Classification
- Neural Network Regression and Classification
- Random Forest Regression and Classification
- Support Vector Regression and Classification

Problems

- Artificial Ant
- Classification
- Clustering
- External Evaluation Problem
- Knapsack
- OneMax
- Quadratic Assignment
- Regression
- Single-Objective Test Function
- Symbolic Classification
- Symbolic Regression
- Traveling Salesman
- User-defined Problem
- Vehicle Routing

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Demonstration Part I: Working with HeuristicLab

- Create, Parameterize and Execute Algorithms
- Save and Load Items
- Create Batch Runs and Experiments
- Multi-core CPUs and Parallelization
- Analyze Runs
- Analyzers
- Building User-Defined Algorithms

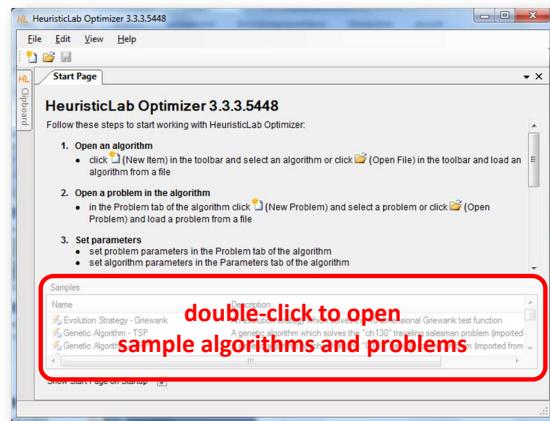


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HeuristicLab Optimizer

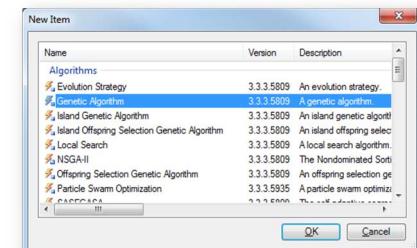
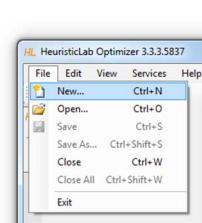


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Create Algorithm

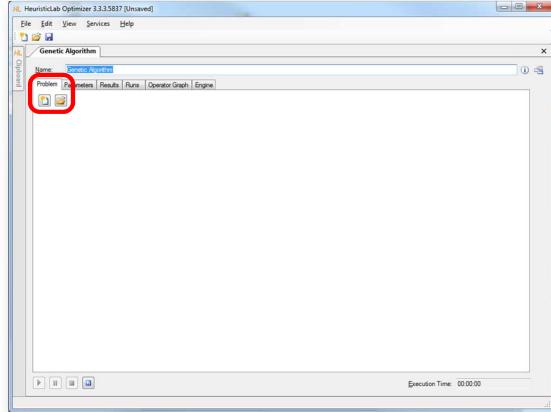


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Create or Load Problem

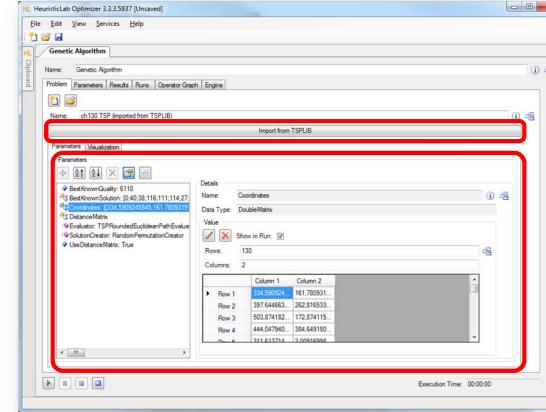


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Import or Parameterize Problem Data

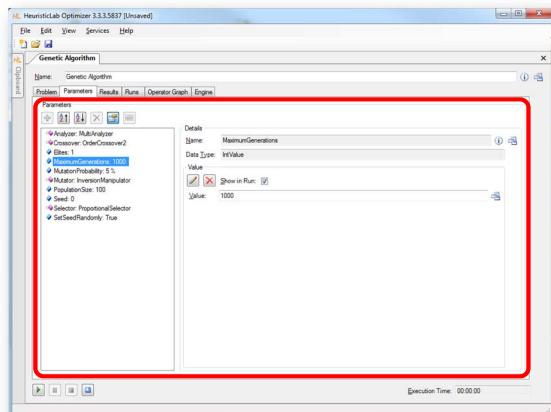


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Parameterize Algorithm

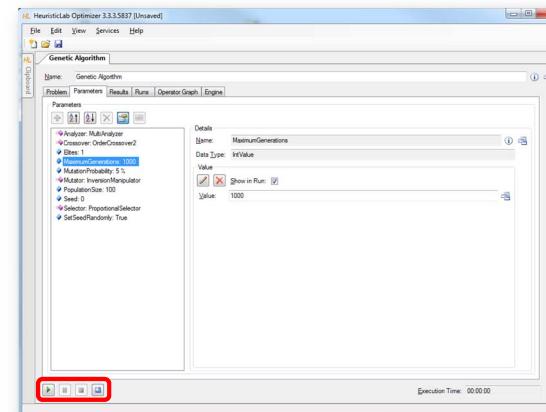


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Start, Pause, Resume, Stop and Reset

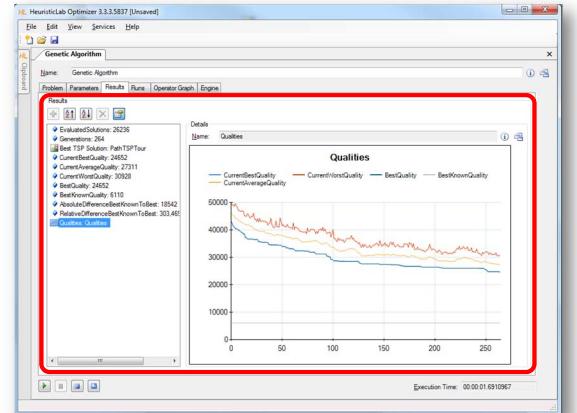


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Inspect Results



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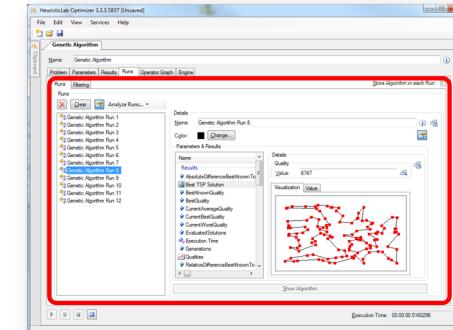


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Compare Runs

- A run is created each time when the algorithm is stopped
 - runs contain all results and parameter settings
 - previous results are not forgotten and can be compared



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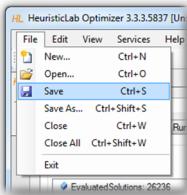


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Save and Load

- Save to and load from disk
 - HeuristicLab items (i.e., algorithms, problems, experiments, ...) can be saved to and loaded from a file
 - algorithms can be paused, saved, loaded and resumed
 - data format is custom compressed XML
 - saving and loading files might take several minutes
 - saving and loading large experiments requires some memory



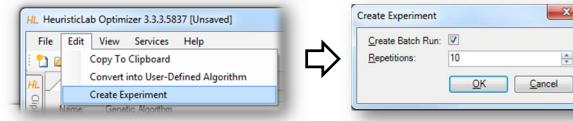
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Create Batch Runs and Experiments

- Batch runs
 - execute the same optimizer (e.g. algorithm, batch run, experiment) several times
- Experiments
 - execute different optimizers
 - suitable for large scale algorithm comparison and analysis
- Experiments and batch runs can be nested
- Generated runs can be compared afterwards



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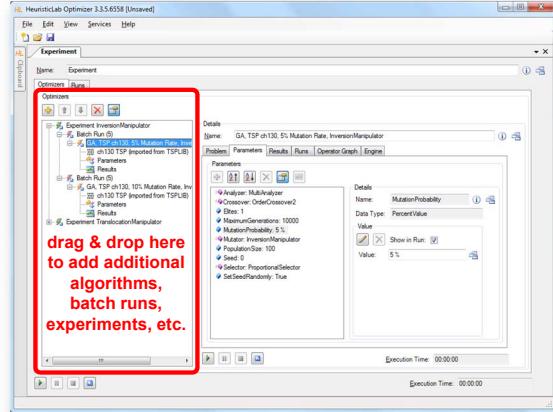
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Create Batch Runs and Experiments



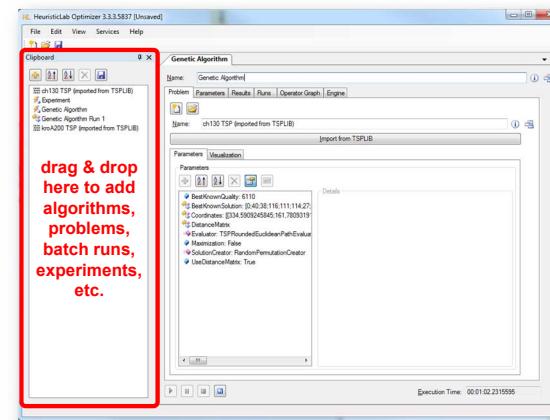
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Clipboard



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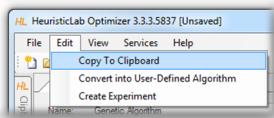


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Clipboard



- Store items
 - click on the buttons to add or remove items
 - drag & drop items on the clipboard
 - use the menu to add a copy of a shown item to the clipboard



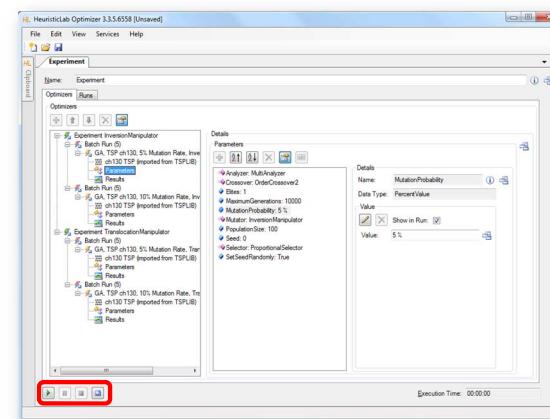
- Show items
 - double-click on an item in the clipboard to show its view
- Save and restore clipboard content
 - click on the save button to write the clipboard content to disk
 - clipboard is automatically restored when HeuristicLab is started the next time

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Start, Pause, Resume, Stop, Reset

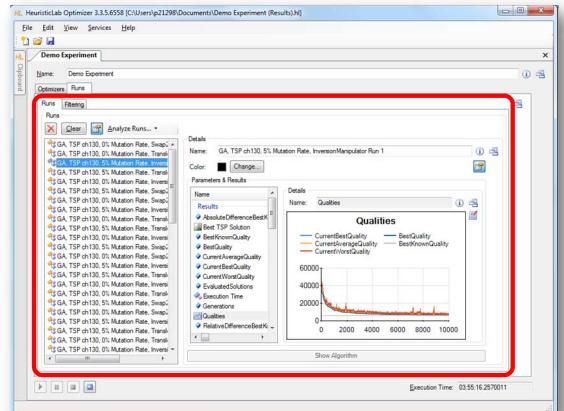


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Compare Runs



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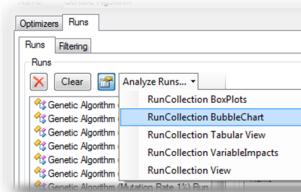
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Analyze Runs



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- HeuristicLab provides interactive views to analyze and compare all runs of a run collection
 - textual analysis
 - RunCollection Tabular View
 - graphical analysis
 - RunCollection BubbleChart
 - RunCollection BoxPlots
- Filtering is automatically applied to all open run collection views



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RunCollection Tabular View

The screenshot shows the 'RunCollection Tabular View' dialog for a 'Genetic Algorithm' run. The table has 48 rows and 6 columns. The columns are: BestKnownQuality, BestKnownSoluton, BestQuality, Coordinates, Crossover, and CurrentAverageQuality. The table lists various runs with their corresponding values.

	BestKnownQuality	BestKnownSoluton	BestQuality	Coordinates	Crossover	CurrentAverageQuality
1	[310]	[04038116111114...]	16405	[334.590245]	OrderCrosso...	18543.13
2	[310]	[04038116111114...]	14703	[334.590245]	OrderCrosso...	15020.02
3	[310]	[04038116111114...]	14205	[334.590245]	OrderCrosso...	14022.39
4	[310]	[04038116111114...]	14243	[334.590245]	OrderCrosso...	14022.59
5	[310]	[04038116111114...]	13703	[334.590245]	OrderCrosso...	13748.98
6	[310]	[04038116111114...]	13564	[334.590245]	OrderCrosso...	13601.09
7	[310]	[04038116111114...]	15421	[334.590245]	OrderCrosso...	15431.74
8	[310]	[04038116111114...]	14409	[334.590245]	OrderCrosso...	15147
9	[310]	[04038116111114...]	13771	[334.590245]	OrderCrosso...	13954.56
10	[310]	[04038116111114...]	14505	[334.590245]	OrderCrosso...	14520.23
11	[310]	[04038116111114...]	14095	[334.590245]	OrderCrosso...	14297.27
12	[310]	[04038116111114...]	12403	[334.590245]	OrderCrosso...	12181.09
13	[310]	[04038116111114...]	14993	[334.590245]	OrderCrosso...	14650.98
14	[310]	[04038116111114...]	12591	[334.590245]	OrderCrosso...	12591.99
15	[310]	[04038116111114...]	12792	[334.590245]	OrderCrosso...	12646.38
16	[310]	[04038116111114...]	12711	[334.590245]	OrderCrosso...	13151.19
17	[310]	[04038116111114...]	12526	[334.590245]	OrderCrosso...	12624.78
18	[310]	[04038116111114...]	12780	[334.590245]	OrderCrosso...	12780.78
19	[310]	[04038116111114...]	12807	[334.590245]	OrderCrosso...	12808.81
20	[310]	[04038116111114...]	12741	[334.590245]	OrderCrosso...	12713.18
21	[310]	[04038116111114...]	15921	[334.590245]	OrderCrosso...	16084.04
22	[310]	[04038116111114...]	16309	[334.590245]	OrderCrosso...	16050.36

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RunCollection Tabular View



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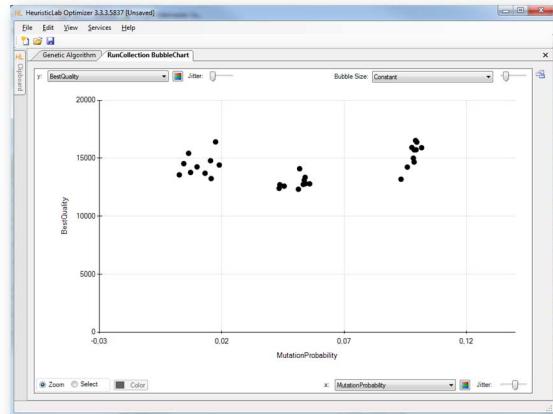
- Sort columns
 - click on column header to sort column
 - Ctrl-click on column header to sort multiple columns
- Show or hide columns
 - right-click on table to open dialog to show or hide columns
- Compute statistical values
 - select multiple numerical values to see count, sum, minimum, maximum, average and standard deviation
- Select, copy and paste into other applications

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RunCollection BubbleChart



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RunCollection BubbleChart



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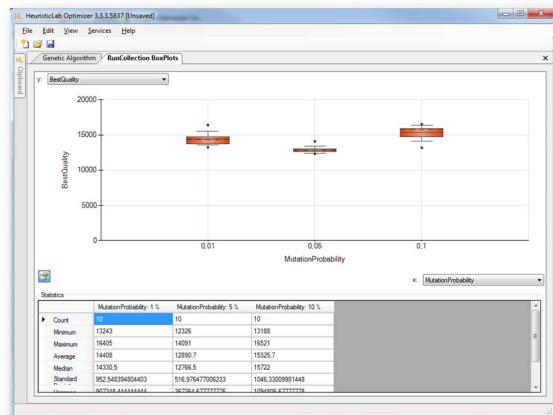
- Choose values to plot
 - choose which values to show on the x-axis, the y-axis and as bubble size
 - possible values are all parameter settings and results
- Add jitter
 - add jitter to separate overlapping bubbles
- Zoom in and out
 - click on Zoom and click and drag in the chart area to zoom in
 - double click on the chart area background or on the circle buttons beside the scroll bars to zoom out
- Color bubbles
 - click on Select, choose a color and click and drag in the chart area to select and color bubbles
 - applying automatically by clicking on the axis coloring buttons
- Show runs
 - double click on a bubble to open its run
- Export image
 - right-click to open context menu to copy or save image
 - save image as pixel (BMP, JPG, PNG, GIF, TIF) or vector graphics (EMF)
- Show box plots
 - right-click to open context menu to show box plots view

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RunCollection BoxPlots



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RunCollection BoxPlots



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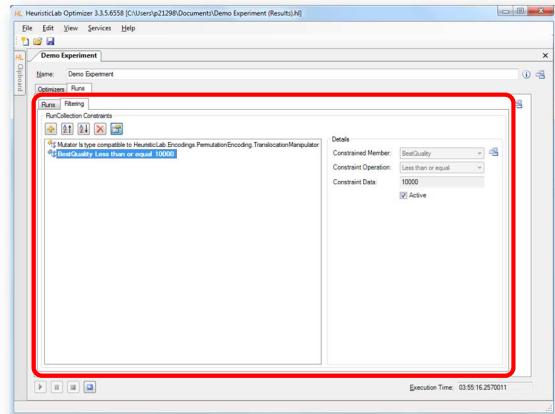
- Choose values to plot
 - choose which values to show on the x-axis and y-axis
 - possible values are all parameter settings and results
- Zoom in and out
 - click on Zoom and click and drag in the chart area to zoom in
 - double click on the chart area background or on the circle buttons beside the scroll bars to zoom out
- Show or hide statistical values
 - click on the lower left button to show or hide statistical values
- Export image
 - right-click to open context menu to copy or save image
 - save image as pixel (BMP, JPG, PNG, GIF, TIF) or vector graphics (EMF)

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Filter Runs



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Multi-core CPUs and Parallelization

- Parallel execution of optimizers in experiments
 - optimizers in an experiment are executed sequentially from top to bottom per default
 - experiments support parallel execution of their optimizers
 - select a not yet executed optimizer and start it manually to utilize another core
 - execution of one of the next optimizers is started automatically after an optimizer is finished
- Parallel execution of algorithms
 - HeuristicLab provides special operators for parallelization
 - engines decide how to execute parallel operations
 - sequential engine executes everything sequentially
 - parallel engine executes parallel operations on multiple cores
 - Hive engine (under development) executes parallel operations on multiple computers
 - all implemented algorithms support parallel solution evaluation

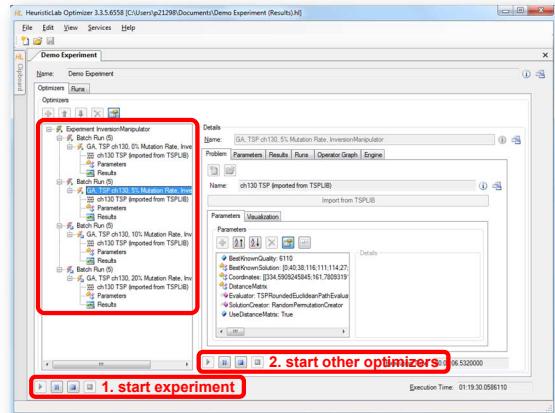
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Parallel Execution of Experiments



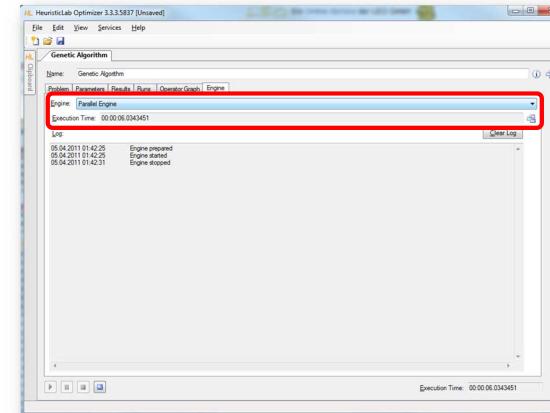
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Parallel Execution of Algorithms



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Analyzers



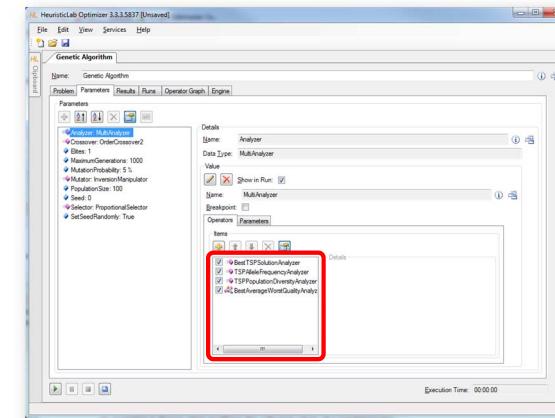
- Special operators for analysis purposes
 - are executed after each iteration
 - serve as general purpose extension points of algorithms
 - can be selected and parameterized in the algorithm
 - perform algorithm-specific and/or problem-specific tasks
 - some analyzers are quite costly regarding runtime and memory
 - implementing and adding custom analyzers is easy
- Examples
 - TSPAlleleFrequencyAnalyzer
 - TSPPopulationDiversityAnalyzer
 - SuccessfulOffspringAnalyzer
 - SymbolicDataAnalysisVariableFrequencyAnalyzer
 - SymbolicRegressionSingleObjectiveTrainingBestSolutionAnalyzer
 - ...

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Analyzers

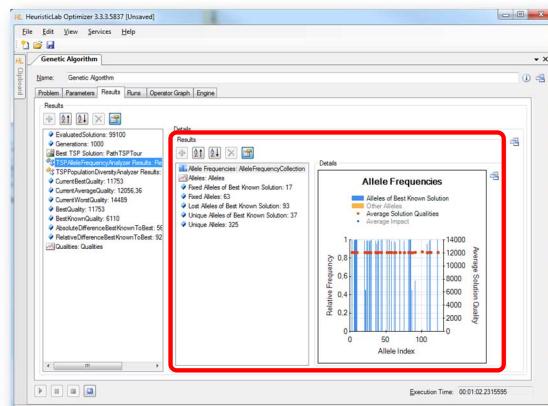


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TSPAlleleFrequencyAnalyzer

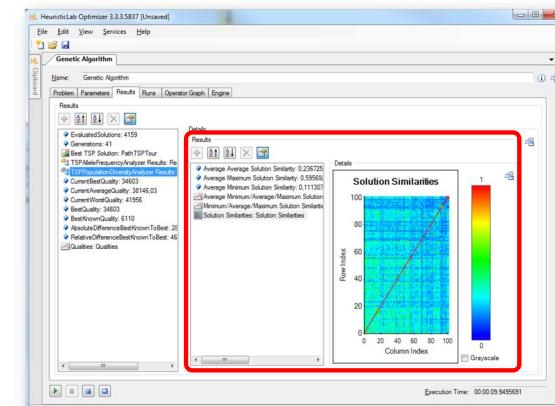


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TSPPopulationDiversityAnalyzer



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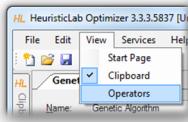
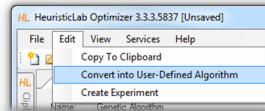
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Building User-Defined Algorithms



- Operator graphs
 - algorithms are represented as operator graphs
 - operator graphs of user-defined algorithms can be changed
 - algorithms can be defined in the graphical algorithm designer
 - use the menu to convert a standard algorithm into a user-defined algorithm



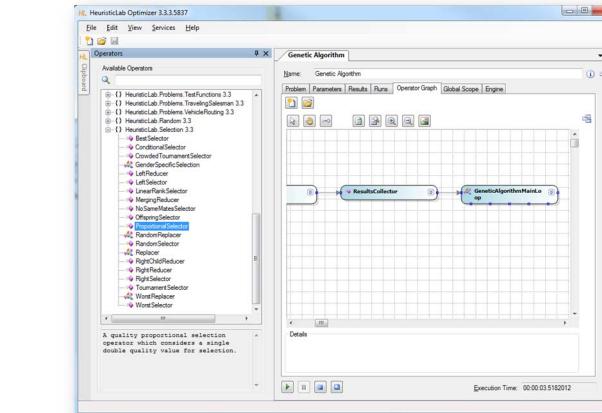
- Operators sidebar
 - drag & drop operators into an operator graph
- Programmable operators
 - add programmable operators in order to implement custom logic in an algorithm
 - no additional development environment needed
- Debug algorithms
 - use the debug engine to obtain detailed information during algorithm execution

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Building User-Defined Algorithms

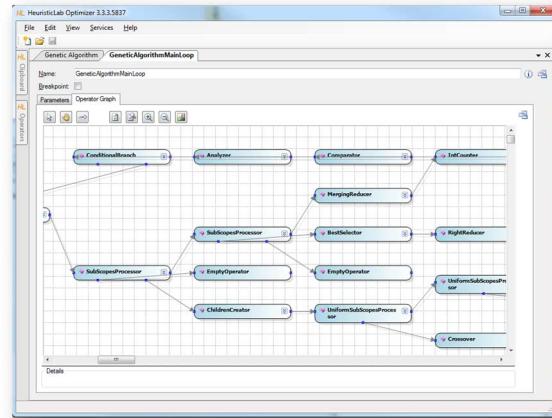


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Building User-Defined Algorithms



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Programmable Operators



```

public class ProgrammableSingleSuccessorOperator : IOperation
{
    public static IOperation Execute(ProgrammableSingleSuccessorOperator op,
        IOperationContext context)
    {
        return op.Successor == null ? null : context.CreateOperation(op.Successor);
    }
}

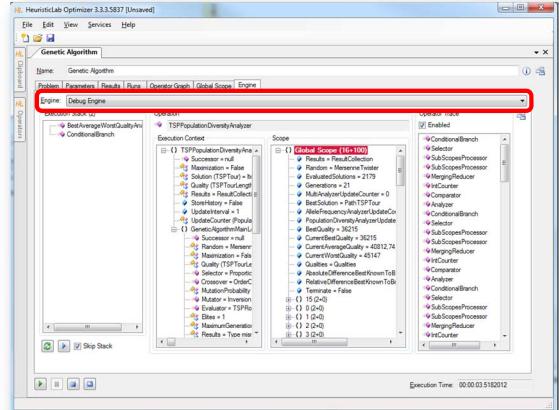
```

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Debugging Algorithms



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<http://dev.heuristiclab.com>



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Agenda

- Objectives of the Tutorial
- Introduction
- Where to get HeuristicLab?
- Plugin Infrastructure
- Graphical User Interface
- Available Algorithms & Problems
- Demonstration Part I: Working with HeuristicLab
- Demonstration Part II: Data-based Modeling
- Some Additional Features
- Planned Features
- Team
- Suggested Readings
- Bibliography
- Questions & Answers

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Demonstration Part II: Data-based Modeling



- Introduction
- Regression with HeuristicLab
- Model simplification and export
- Variable relevance analysis
- Classification with HeuristicLab

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Introduction to Data-based Modeling



- Dataset: Matrix $(x_{i,j})_{i=1..N, j=1..K}$
 - N observations of K input variables
 - $x_{i,j}$ = i-th observation of j-th variable
 - Additionally: Vector of labels $(y_1 \dots y_N)^T$
- Goal: learn association of input variable values to labels
- Common tasks
 - Regression (real-valued labels)
 - Classification (discrete labels)
 - Clustering (no labels, group similar observations)

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Data-based Modeling Algorithms in HeuristicLab



- Symbolic regression and classification based on genetic programming
- External Libraries:
 - Support Vector Machines for Regression and Classification
 - Linear Regression
 - Linear Discriminate Analysis
 - K-Means clustering

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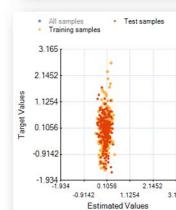
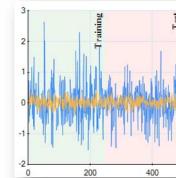
Case Studies

- Demonstration
 - problem configuration
 - data import
 - target variable
 - input variables
 - data partitions (training and test)
 - analysis of results
 - accuracy metrics
 - visualization of model output



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Case Study: Regression



- Poly-10 benchmark problem dataset
 - 10 input variables $x_1 \dots x_{10}$
 - $y = x_1 \cdot x_2 + x_3 \cdot x_4 + x_5 \cdot x_6 + x_1 \cdot x_7 \cdot x_9 + x_3 \cdot x_6 \cdot x_{10}$
 - non-linear modeling approach necessary
 - frequently used in GP literature
 - download
<http://dev.heuristiclab.com/AdditionalMaterial#GECCO2012>

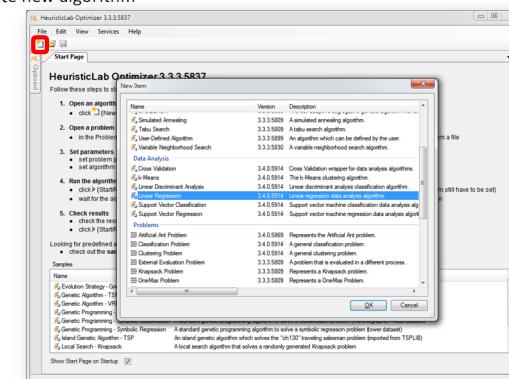
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Linear Regression

- Create new algorithm

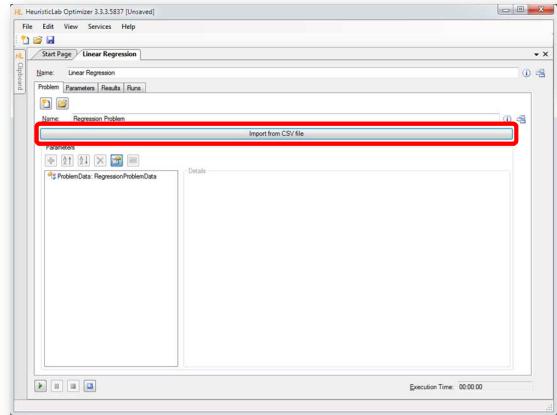


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Import Data from CSV-File

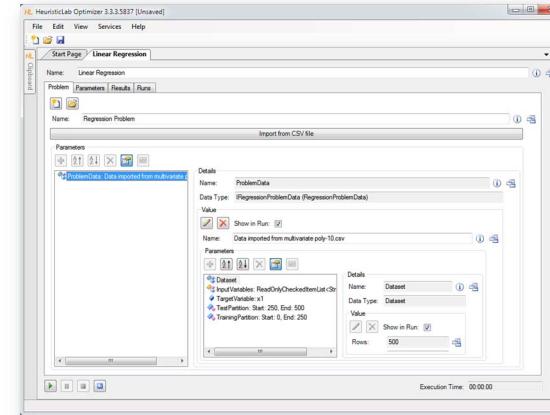


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Inspect and Configure Dataset

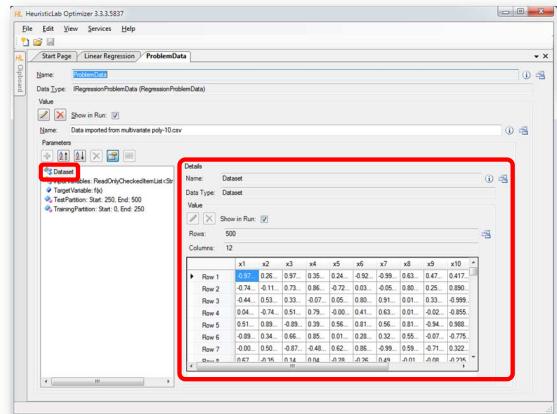


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Inspect Imported Data

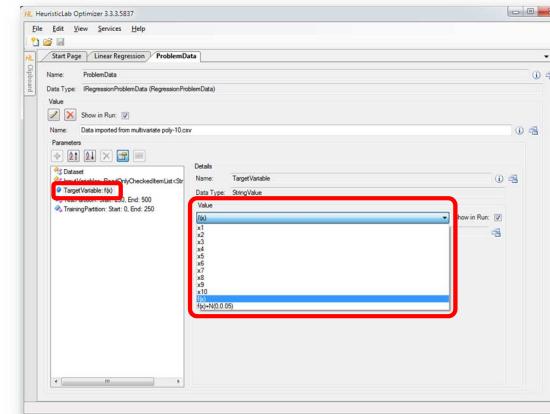


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Set Target Variable

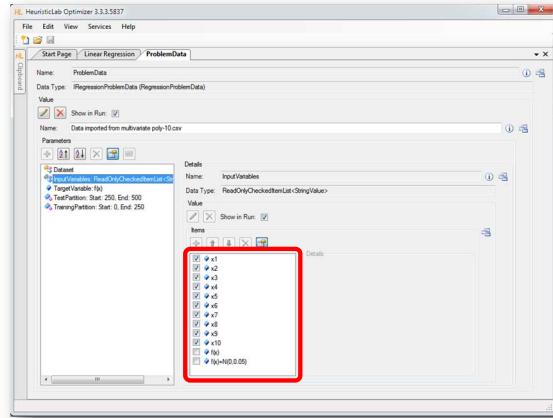


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Select Input Variables

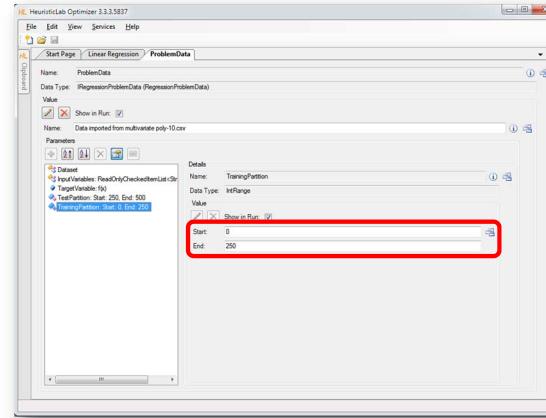


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Configure Training and Test Partitions

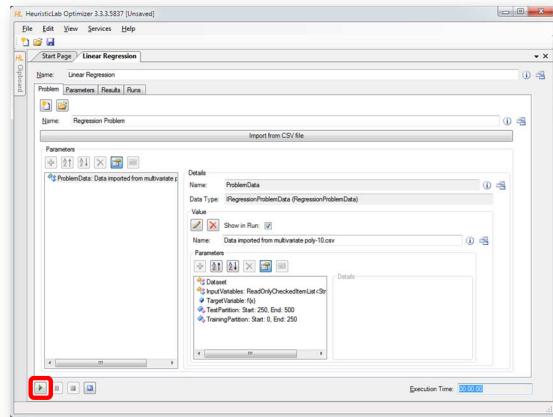


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Run Linear Regression

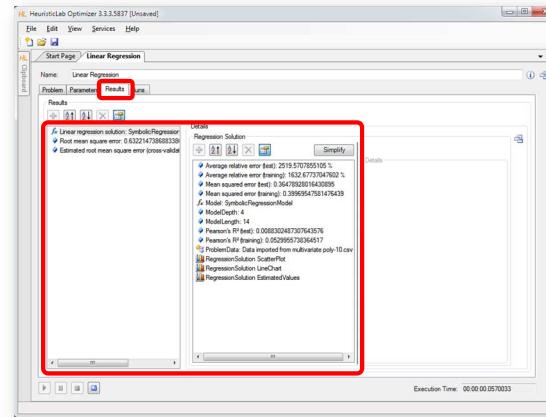


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Inspect Results

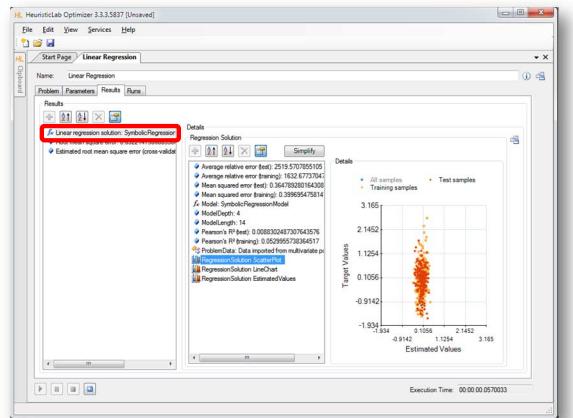


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Inspect Scatterplot of Predicted and Target Values



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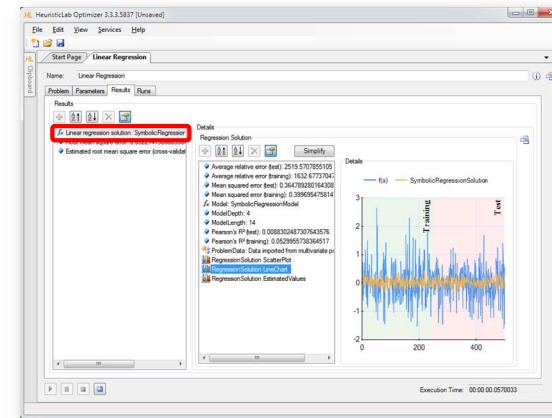
<http://dev.heuristiclab.com>



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Inspect Linechart



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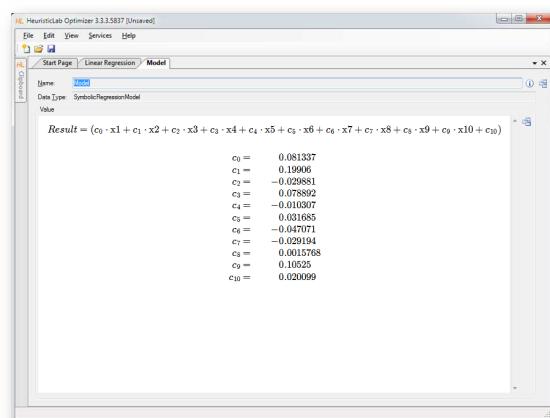
<http://dev.heuristiclab.com>



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Inspect the Model



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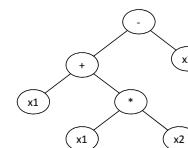
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Symbolic Regression with HeuristicLab



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- Linear regression produced an inaccurate model.
- Next: produce a nonlinear symbolic regression model using genetic programming
- Genetic programming
 - evolve variable-length models
 - model representation: symbolic expression tree
 - structure and model parameters are evolved side-by-side
 - white-box models



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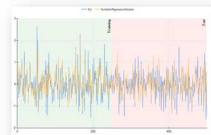
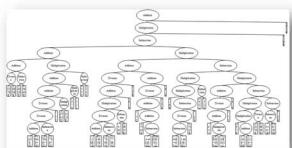
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Symbolic Regression with HeuristicLab



- Demonstration
 - problem configuration
 - function set and terminal set
 - model size constraints
 - Evaluation
- Algorithm configuration
 - selection
 - Mutation
- Analysis of results
 - model accuracy
 - model structure and parameters

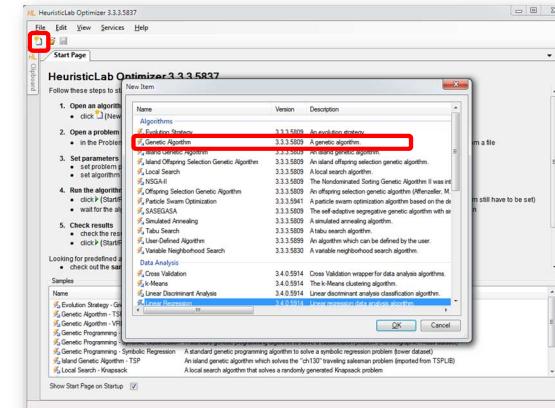


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Create New Genetic Algorithm

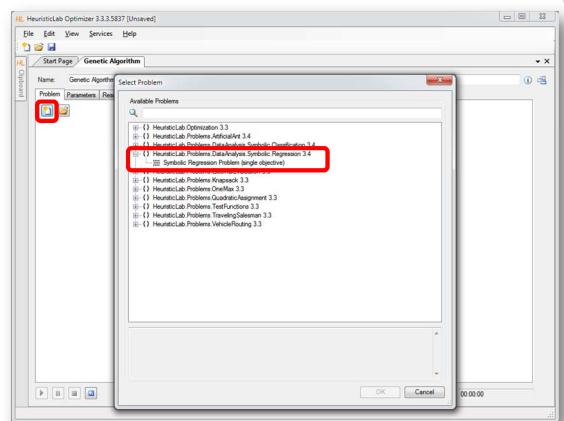


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Create New Symbolic Regression Problem

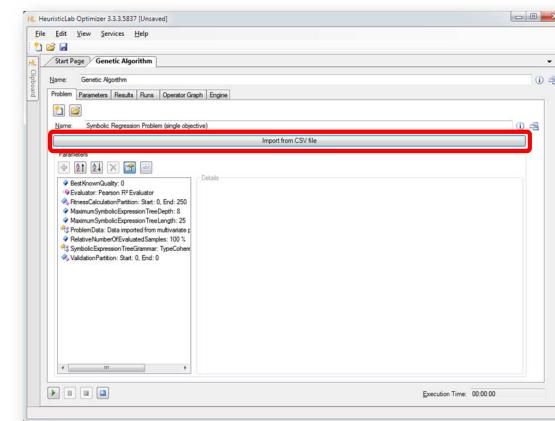


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Import Data

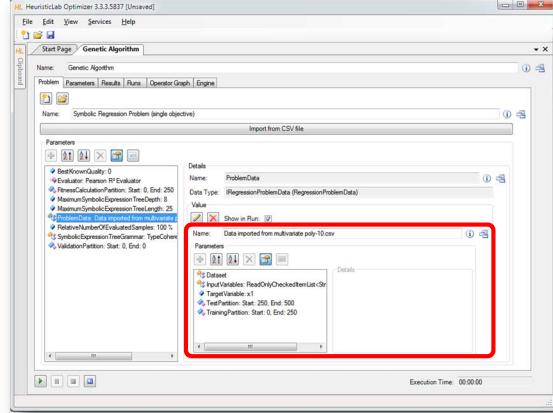


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Inspect Data and Configure Dataset



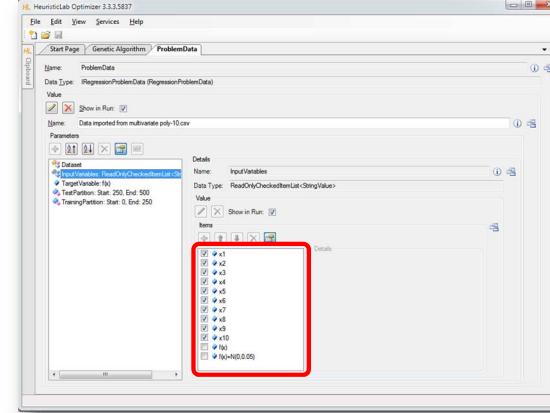
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Set Target and Input Variables



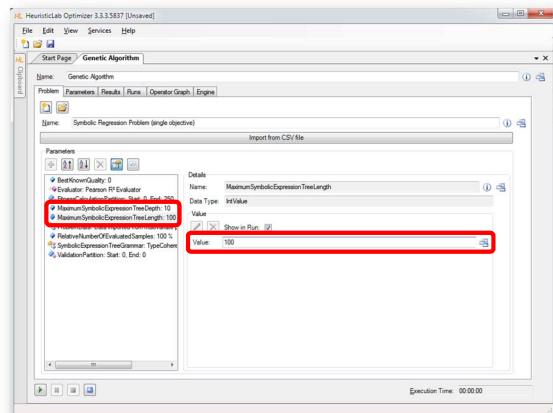
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Configure Maximal Model Depth and Length



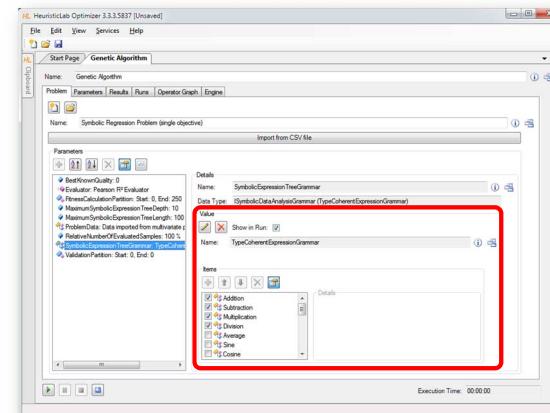
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Configure Function Set (Grammar)



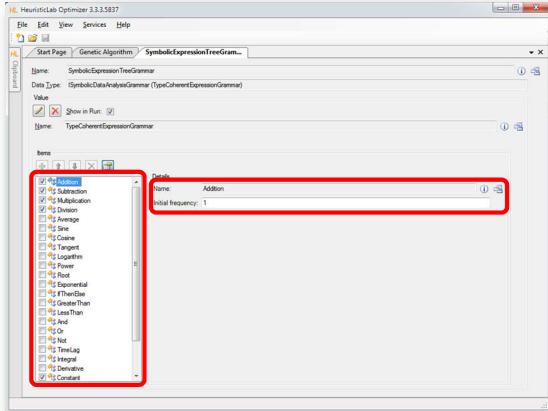
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Configure Function Set (Grammar)

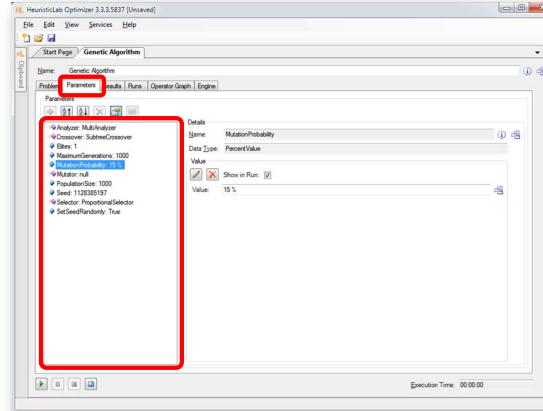


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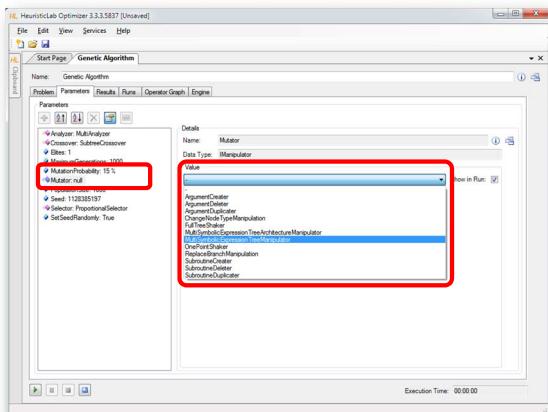
Configure Algorithm Parameters



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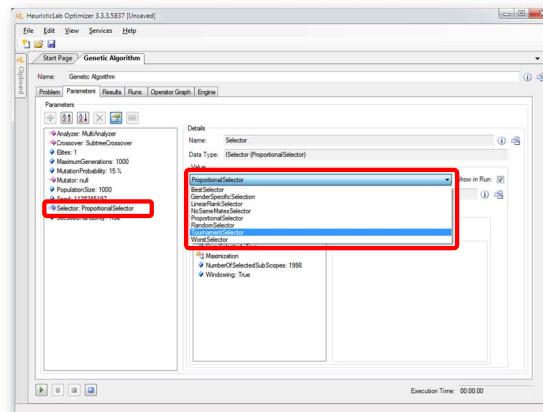
Configure Mutation Operator



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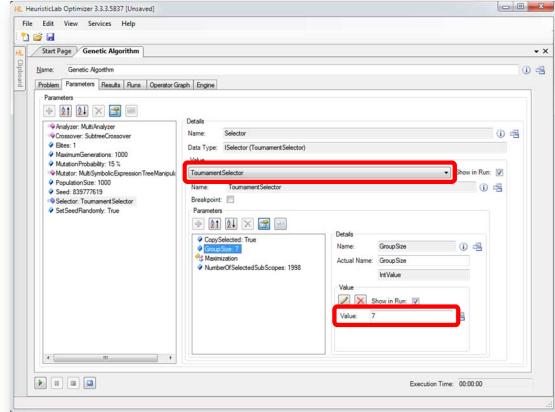
Configure Selection Operator



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Configure Tournament Group Size



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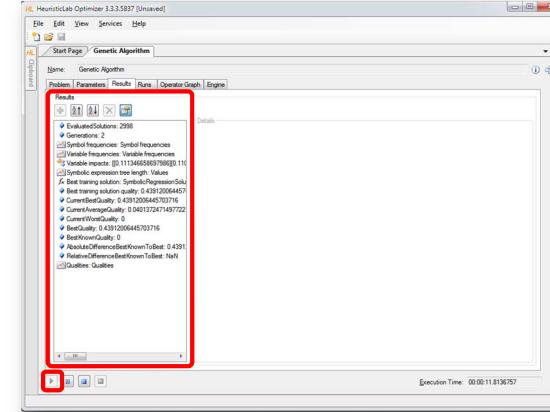
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Start Algorithm and Inspect Results



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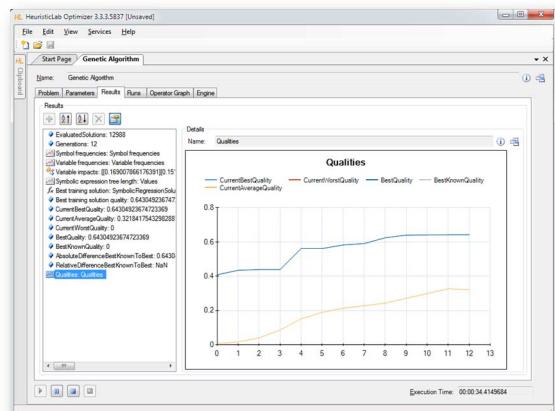
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Inspect Quality Chart



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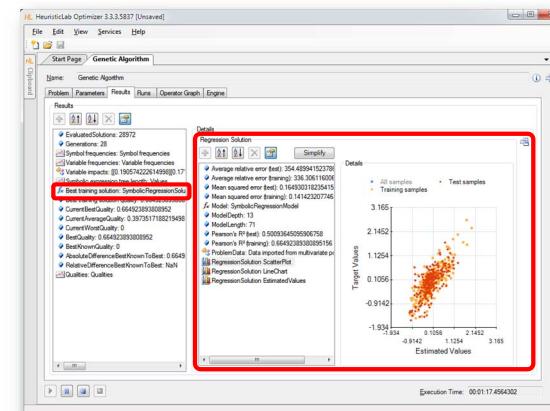
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Inspect Best Model on Training Partition



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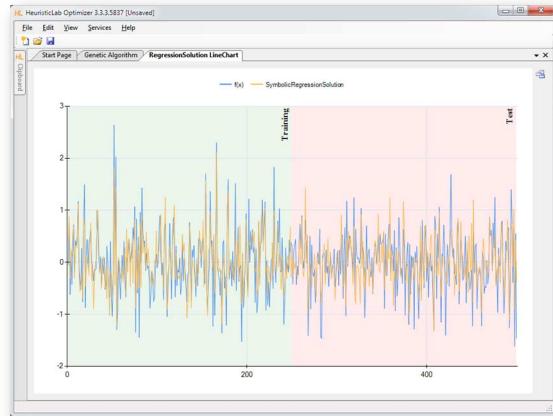
<http://dev.heuristiclab.com>



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Inspect Linechart of Best Model on Training Partition

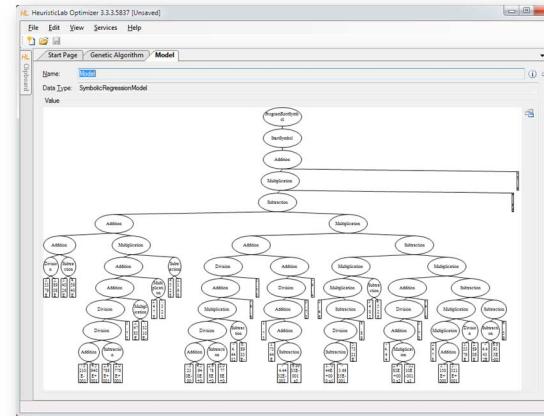


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Inspect Structure of Best Model on Training Partition



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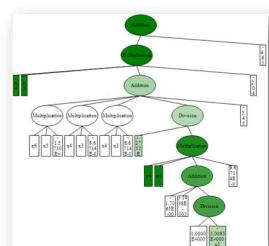
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Model Simplification and Export



- Demonstration
 - automatic simplification
 - visualization of node impacts
 - manual simplification
 - online update of results
 - model export
 - MATLAB
 - LaTeX



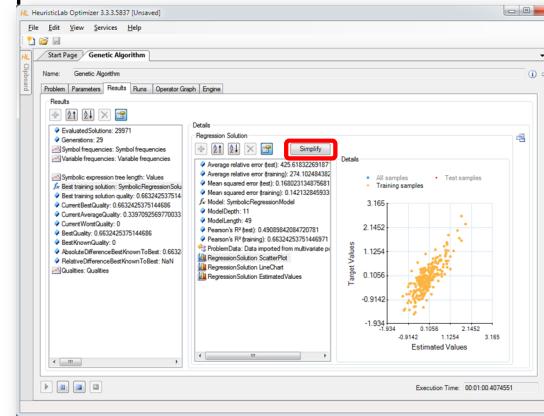
$$\text{Result} = x4(t) \cdot x3(t) \cdot c_{20} \\ \cdot \left(x6(t) \cdot x5(t) \cdot c_4 + x4(t) \cdot x3(t) \cdot c_7 + x4(t) \cdot x3(t) \cdot c_{10} + \frac{c_{11}x2(t)}{x4(t) \cdot x3(t) \cdot (c_{14}x4(t) + c_{15}x5(t) + \frac{1}{c_{18}x2(t)})} + c_{21} \right)$$

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Detailed Model Analysis and Simplification

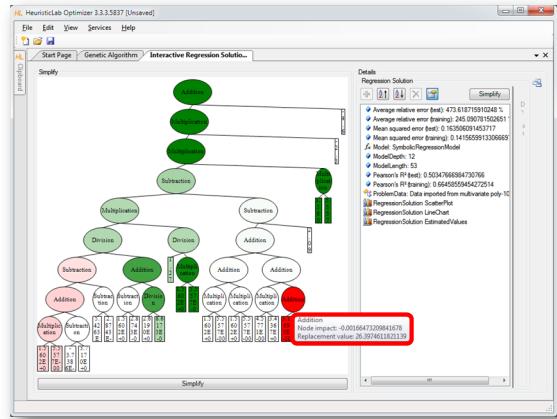


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Symbolic Simplification and Node Impacts

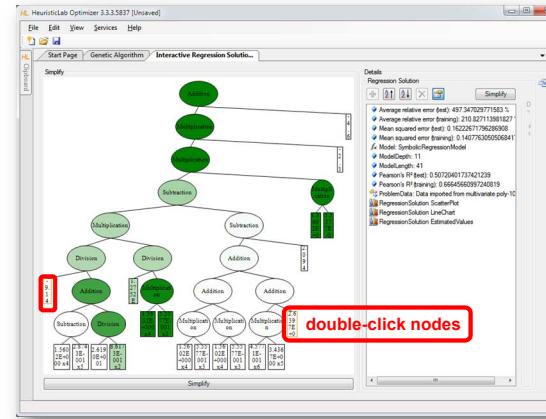


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Manual Simplification

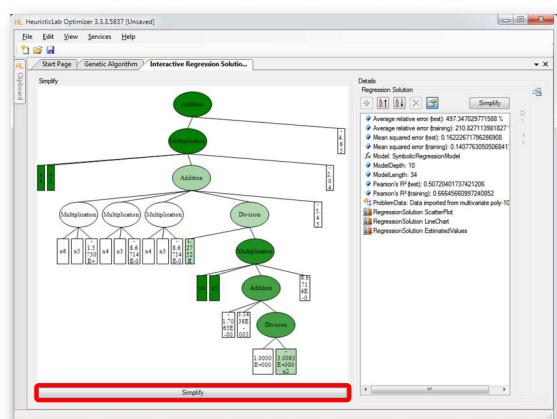


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Automatic Symbolic Simplification



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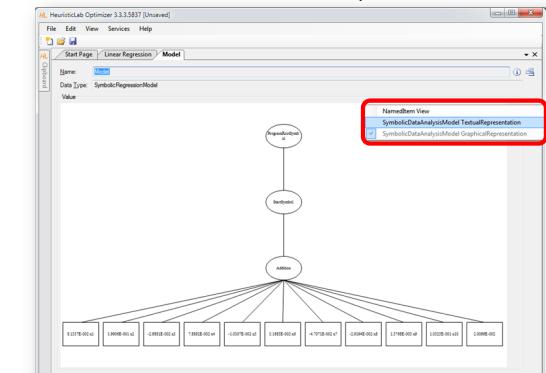
<http://dev.heuristiclab.com>

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Textual Representations Are Also Available



- Use ViewHost to switch to textual representation view.



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Default Textual Representation for Model Export



```
HeuristicLab Optimizer 3.3.3.5837 [Unsaved]
File Edit View Services Help
HL Start Page | Linear Regression > Model
Name: Model
Data Type: SymbolicRegressionModel
Value:
Formatter: Default String Formatter
(ProgRootSymbol
(StartSymbol
Addition
(B.133E-002*x)
(+0.133E-002*x)
(-2.881E-002*x)
(+1.007E-002*x)
(-0.000E+000*x)
(+0.000E+000*x)
(-4.701E-002*x)
(+1.000E-002*x)
(+1.976E-003*x)
(+1.000E-010*x)
(2.099E-002*x)
)
```

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Textual Representation for Export to LaTeX



```
HeuristicLab Optimizer 3.3.3.5837 [Unsaved]
File Edit View Services Help
HL Start Page | Linear Regression > Model
Name: Model
Data Type: SymbolicRegressionModel
Value:
Formatter: LaTeX String Compiler
\needs{upackage{amsmath}}
\begin{aligned}
&\text{Result} = (c_1 x_{11}) + c_1 x_{21} (t) + c_1 x_{31} (t) + c_1 x_{41} (t) + c_1 x_{51} (t) + c_1 x_{61} (t) + c_1 x_{71} (t) + c_1 x_{81} (t) + c_1 x_{91} (t) + c_1 x_{101} (t) + c_1 x_{111} (t) \\
&c_1 = 0.08137224247391 \\
&c_2 = -0.02109818171462938 \\
&c_3 = 0.0296011744620391 \\
&c_4 = 0.0103065733662221 \\
&c_5 = 0.000103065733662221 \\
&c_6 = 0.0470795925129 \\
&c_7 = 0.0015767665070175 \\
&c_8 = 0.0151796450779 \\
&c_9 = 0.0015767665070175 \\
&c_{10} = 0.02009874646293256
\end{aligned}
```

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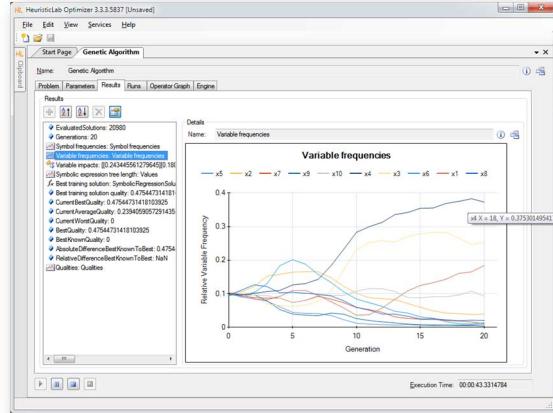
94

LaTeX Export



```
HeuristicLab Optimizer 3.3.3.5837 [Unsaved]
File Edit View Services Help
HL Start Page | Genetic Algorithm > Interactive Regression Solution > Model
Name: Model
Data Type: SymbolicRegressionModel
Value:
Formatter: LaTeX String Formatter
\needs{upackage{amsmath}}
\begin{aligned}
\text{Result} &= (c_1 x_{11}) + c_1 x_{21} (t) + c_1 x_{31} (t) + c_1 x_{41} (t) + c_1 x_{51} (t) + c_1 x_{61} (t) + c_1 x_{71} (t) + c_1 x_{81} (t) + c_1 x_{91} (t) + c_1 x_{101} (t) + c_1 x_{111} (t) \\
&+ c_2 x_{12} (t) + c_2 x_{22} (t) + c_2 x_{32} (t) + c_2 x_{42} (t) + c_2 x_{52} (t) + c_2 x_{62} (t) + c_2 x_{72} (t) + c_2 x_{82} (t) + c_2 x_{92} (t) + c_2 x_{102} (t) + c_2 x_{112} (t) \\
&+ c_3 x_{13} (t) + c_3 x_{23} (t) + c_3 x_{33} (t) + c_3 x_{43} (t) + c_3 x_{53} (t) + c_3 x_{63} (t) + c_3 x_{73} (t) + c_3 x_{83} (t) + c_3 x_{93} (t) + c_3 x_{103} (t) + c_3 x_{113} (t) \\
&+ c_4 x_{14} (t) + c_4 x_{24} (t) + c_4 x_{34} (t) + c_4 x_{44} (t) + c_4 x_{54} (t) + c_4 x_{64} (t) + c_4 x_{74} (t) + c_4 x_{84} (t) + c_4 x_{94} (t) + c_4 x_{104} (t) + c_4 x_{114} (t) \\
&+ c_5 x_{15} (t) + c_5 x_{25} (t) + c_5 x_{35} (t) + c_5 x_{45} (t) + c_5 x_{55} (t) + c_5 x_{65} (t) + c_5 x_{75} (t) + c_5 x_{85} (t) + c_5 x_{95} (t) + c_5 x_{105} (t) + c_5 x_{115} (t) \\
&+ c_6 x_{16} (t) + c_6 x_{26} (t) + c_6 x_{36} (t) + c_6 x_{46} (t) + c_6 x_{56} (t) + c_6 x_{66} (t) + c_6 x_{76} (t) + c_6 x_{86} (t) + c_6 x_{96} (t) + c_6 x_{106} (t) + c_6 x_{116} (t) \\
&+ c_7 x_{17} (t) + c_7 x_{27} (t) + c_7 x_{37} (t) + c_7 x_{47} (t) + c_7 x_{57} (t) + c_7 x_{67} (t) + c_7 x_{77} (t) + c_7 x_{87} (t) + c_7 x_{97} (t) + c_7 x_{107} (t) + c_7 x_{117} (t) \\
&+ c_8 x_{18} (t) + c_8 x_{28} (t) + c_8 x_{38} (t) + c_8 x_{48} (t) + c_8 x_{58} (t) + c_8 x_{68} (t) + c_8 x_{78} (t) + c_8 x_{88} (t) + c_8 x_{98} (t) + c_8 x_{108} (t) + c_8 x_{118} (t) \\
&+ c_9 x_{19} (t) + c_9 x_{29} (t) + c_9 x_{39} (t) + c_9 x_{49} (t) + c_9 x_{59} (t) + c_9 x_{69} (t) + c_9 x_{79} (t) + c_9 x_{89} (t) + c_9 x_{99} (t) + c_9 x_{109} (t) + c_9 x_{119} (t) \\
&+ c_{10} x_{20} (t) + c_{10} x_{30} (t) + c_{10} x_{40} (t) + c_{10} x_{50} (t) + c_{10} x_{60} (t) + c_{10} x_{70} (t) + c_{10} x_{80} (t) + c_{10} x_{90} (t) + c_{10} x_{100} (t) + c_{10} x_{110} (t) \\
&+ c_{11} x_{21} (t) + c_{11} x_{31} (t) + c_{11} x_{41} (t) + c_{11} x_{51} (t) + c_{11} x_{61} (t) + c_{11} x_{71} (t) + c_{11} x_{81} (t) + c_{11} x_{91} (t) + c_{11} x_{101} (t) + c_{11} x_{111} (t) \\
&+ c_{12} x_{22} (t) + c_{12} x_{32} (t) + c_{12} x_{42} (t) + c_{12} x_{52} (t) + c_{12} x_{62} (t) + c_{12} x_{72} (t) + c_{12} x_{82} (t) + c_{12} x_{92} (t) + c_{12} x_{102} (t) + c_{12} x_{112} (t) \\
&+ c_{13} x_{23} (t) + c_{13} x_{33} (t) + c_{13} x_{43} (t) + c_{13} x_{53} (t) + c_{13} x_{63} (t) + c_{13} x_{73} (t) + c_{13} x_{83} (t) + c_{13} x_{93} (t) + c_{13} x_{103} (t) + c_{13} x_{113} (t) \\
&+ c_{14} x_{24} (t) + c_{14} x_{34} (t) + c_{14} x_{44} (t) + c_{14} x_{54} (t) + c_{14} x_{64} (t) + c_{14} x_{74} (t) + c_{14} x_{84} (t) + c_{14} x_{94} (t) + c_{14} x_{104} (t) + c_{14} x_{114} (t) \\
&+ c_{15} x_{25} (t) + c_{15} x_{35} (t) + c_{15} x_{45} (t) + c_{15} x_{55} (t) + c_{15} x_{65} (t) + c_{15} x_{75} (t) + c_{15} x_{85} (t) + c_{15} x_{95} (t) + c_{15} x_{105} (t) + c_{15} x_{115} (t) \\
&+ c_{16} x_{26} (t) + c_{16} x_{36} (t) + c_{16} x_{46} (t) + c_{16} x_{56} (t) + c_{16} x_{66} (t) + c_{16} x_{76} (t) + c_{16} x_{86} (t) + c_{16} x_{96} (t) + c_{16} x_{106} (t) + c_{16} x_{116} (t) \\
&+ c_{17} x_{27} (t) + c_{17} x_{37} (t) + c_{17} x_{47} (t) + c_{17} x_{57} (t) + c_{17} x_{67} (t) + c_{17} x_{77} (t) + c_{17} x_{87} (t) + c_{17} x_{97} (t) + c_{17} x_{107} (t) + c_{17} x_{117} (t) \\
&+ c_{18} x_{28} (t) + c_{18} x_{38} (t) + c_{18} x_{48} (t) + c_{18} x_{58} (t) + c_{18} x_{68} (t) + c_{18} x_{78} (t) + c_{18} x_{88} (t) + c_{18} x_{98} (t) + c_{18} x_{108} (t) + c_{18} x_{118} (t) \\
&+ c_{19} x_{29} (t) + c_{19} x_{39} (t) + c_{19} x_{49} (t) + c_{19} x_{59} (t) + c_{19} x_{69} (t) + c_{19} x_{79} (t) + c_{19} x_{89} (t) + c_{19} x_{99} (t) + c_{19} x_{109} (t) + c_{19} x_{119} (t) \\
&+ c_{20} x_{30} (t) + c_{20} x_{40} (t) + c_{20} x_{50} (t) + c_{20} x_{60} (t) + c_{20} x_{70} (t) + c_{20} x_{80} (t) + c_{20} x_{90} (t) + c_{20} x_{100} (t) + c_{20} x_{110} (t) \\
&+ c_{21} x_{31} (t) + c_{21} x_{41} (t) + c_{21} x_{51} (t) + c_{21} x_{61} (t) + c_{21} x_{71} (t) + c_{21} x_{81} (t) + c_{21} x_{91} (t) + c_{21} x_{101} (t) + c_{21} x_{111} (t) \\
&+ c_{22} x_{32} (t) + c_{22} x_{42} (t) + c_{22} x_{52} (t) + c_{22} x_{62} (t) + c_{22} x_{72} (t) + c_{22} x_{82} (t) + c_{22} x_{92} (t) + c_{22} x_{102} (t) + c_{22} x_{112} (t) \\
&+ c_{23} x_{33} (t) + c_{23} x_{43} (t) + c_{23} x_{53} (t) + c_{23} x_{63} (t) + c_{23} x_{73} (t) + c_{23} x_{83} (t) + c_{23} x_{93} (t) + c_{23} x_{103} (t) + c_{23} x_{113} (t) \\
&+ c_{24} x_{34} (t) + c_{24} x_{44} (t) + c_{24} x_{54} (t) + c_{24} x_{64} (t) + c_{24} x_{74} (t) + c_{24} x_{84} (t) + c_{24} x_{94} (t) + c_{24} x_{104} (t) + c_{24} x_{114} (t) \\
&+ c_{25} x_{35} (t) + c_{25} x_{45} (t) + c_{25} x_{55} (t) + c_{25} x_{65} (t) + c_{25} x_{75} (t) + c_{25} x_{85} (t) + c_{25} x_{95} (t) + c_{25} x_{105} (t) + c_{25} x_{115} (t) \\
&+ c_{26} x_{36} (t) + c_{26} x_{46} (t) + c_{26} x_{56} (t) + c_{26} x_{66} (t) + c_{26} x_{76} (t) + c_{26} x_{86} (t) + c_{26} x_{96} (t) + c_{26} x_{106} (t) + c_{26} x_{116} (t) \\
&+ c_{27} x_{37} (t) + c_{27} x_{47} (t) + c_{27} x_{57} (t) + c_{27} x_{67} (t) + c_{27} x_{77} (t) + c_{27} x_{87} (t) + c_{27} x_{97} (t) + c_{27} x_{107} (t) + c_{27} x_{117} (t) \\
&+ c_{28} x_{38} (t) + c_{28} x_{48} (t) + c_{28} x_{58} (t) + c_{28} x_{68} (t) + c_{28} x_{78} (t) + c_{28} x_{88} (t) + c_{28} x_{98} (t) + c_{28} x_{108} (t) + c_{28} x_{118} (t) \\
&+ c_{29} x_{39} (t) + c_{29} x_{49} (t) + c_{29} x_{59} (t) + c_{29} x_{69} (t) + c_{29} x_{79} (t) + c_{29} x_{89} (t) + c_{29} x_{99} (t) + c_{29} x_{109} (t) + c_{29} x_{119} (t) \\
&+ c_{30} x_{40} (t) + c_{30} x_{50} (t) + c_{30} x_{60} (t) + c_{30} x_{70} (t) + c_{30} x_{80} (t) + c_{30} x_{90} (t) + c_{30} x_{100} (t) + c_{30} x_{110} (t) \\
&+ c_{31} x_{41} (t) + c_{31} x_{51} (t) + c_{31} x_{61} (t) + c_{31} x_{71} (t) + c_{31} x_{81} (t) + c_{31} x_{91} (t) + c_{31} x_{101} (t) + c_{31} x_{111} (t) \\
&+ c_{32} x_{42} (t) + c_{32} x_{52} (t) + c_{32} x_{62} (t) + c_{32} x_{72} (t) + c_{32} x_{82} (t) + c_{32} x_{92} (t) + c_{32} x_{102} (t) + c_{32} x_{112} (t) \\
&+ c_{33} x_{43} (t) + c_{33} x_{53} (t) + c_{33} x_{63} (t) + c_{33} x_{73} (t) + c_{33} x_{83} (t) + c_{33} x_{93} (t) + c_{33} x_{103} (t) + c_{33} x_{113} (t) \\
&+ c_{34} x_{44} (t) + c_{34} x_{54} (t) + c_{34} x_{64} (t) + c_{34} x_{74} (t) + c_{34} x_{84} (t) + c_{34} x_{94} (t) + c_{34} x_{104} (t) + c_{34} x_{114} (t) \\
&+ c_{35} x_{45} (t) + c_{35} x_{55} (t) + c_{35} x_{65} (t) + c_{35} x_{75} (t) + c_{35} x_{85} (t) + c_{35} x_{95} (t) + c_{35} x_{105} (t) + c_{35} x_{115} (t) \\
&+ c_{36} x_{46} (t) + c_{36} x_{56} (t) + c_{36} x_{66} (t) + c_{36} x_{76} (t) + c_{36} x_{86} (t) + c_{36} x_{96} (t) + c_{36} x_{106} (t) + c_{36} x_{116} (t) \\
&+ c_{37} x_{47} (t) + c_{37} x_{57} (t) + c_{37} x_{67} (t) + c_{37} x_{77} (t) + c_{37} x_{87} (t) + c_{37} x_{97} (t) + c_{37} x_{107} (t) + c_{37} x_{117} (t) \\
&+ c_{38} x_{48} (t) + c_{38} x_{58} (t) + c_{38} x_{68} (t) + c_{38} x_{78} (t) + c_{38} x_{88} (t) + c_{38} x_{98} (t) + c_{38} x_{108} (t) + c_{38} x_{118} (t) \\
&+ c_{39} x_{49} (t) + c_{39} x_{59} (t) + c_{39} x_{69} (t) + c_{39} x_{79} (t) + c_{39} x_{89} (t) + c_{39} x_{99} (t) + c_{39} x_{109} (t) + c_{39} x_{119} (t) \\
&+ c_{40} x_{50} (t) + c_{40} x_{60} (t) + c_{40} x_{70} (t) + c_{40} x_{80} (t) + c_{40} x_{90} (t) + c_{40} x_{100} (t) + c_{40} x_{110} (t) \\
&+ c_{41} x_{51} (t) + c_{41} x_{61} (t) + c_{41} x_{71} (t) + c_{41} x_{81} (t) + c_{41} x_{91} (t) + c_{41} x_{101} (t) + c_{41} x_{111} (t) \\
&+ c_{42} x_{52} (t) + c_{42} x_{62} (t) + c_{42} x_{72} (t) + c_{42} x_{82} (t) + c_{42} x_{92} (t) + c_{42} x_{102} (t) + c_{42} x_{112} (t) \\
&+ c_{43} x_{53} (t) + c_{43} x_{63} (t) + c_{43} x_{73} (t) + c_{43} x_{83} (t) + c_{43} x_{93} (t) + c_{43} x_{103} (t) + c_{43} x_{113} (t) \\
&+ c_{44} x_{54} (t) + c_{44} x_{64} (t) + c_{44} x_{74} (t) + c_{44} x_{84} (t) + c_{44} x_{94} (t) + c_{44} x_{104} (t) + c_{44} x_{114} (t) \\
&+ c_{45} x_{55} (t) + c_{45} x_{65} (t) + c_{45} x_{75} (t) + c_{45} x_{85} (t) + c_{45} x_{95} (t) + c_{45} x_{105} (t) + c_{45} x_{115} (t) \\
&+ c_{46} x_{56} (t) + c_{46} x_{66} (t) + c_{46} x_{76} (t) + c_{46} x_{86} (t) + c_{46} x_{96} (t) + c_{46} x_{106} (t) + c_{46} x_{116} (t) \\
&+ c_{47} x_{57} (t) + c_{47} x_{67} (t) + c_{47} x_{77} (t) + c_{47} x_{87} (t) + c_{47} x_{97} (t) + c_{47} x_{107} (t) + c_{47} x_{117} (t) \\
&+ c_{48} x_{58} (t) + c_{48} x_{68} (t) + c_{48} x_{78} (t) + c_{48} x_{88} (t) + c_{48} x_{98} (t) + c_{48} x_{108} (t) + c_{48} x_{118} (t) \\
&+ c_{49} x_{59} (t) + c_{49} x_{69} (t) + c_{49} x_{79} (t) + c_{49} x_{89} (t) + c_{49} x_{99} (t) + c_{49} x_{109} (t) + c_{49} x_{119} (t) \\
&+ c_{50} x_{60} (t) + c_{50} x_{70} (t) + c_{50} x_{80} (t) + c_{50} x_{90} (t) + c_{50} x_{100} (t) + c_{50} x_{110} (t) \\
&+ c_{51} x_{61} (t) + c_{51} x_{71} (t) + c_{51} x_{81} (t) + c_{51} x_{91} (t) + c_{51} x_{101} (t) + c_{51} x_{111} (t) \\
&+ c_{52} x_{62} (t) + c_{52} x_{72} (t) + c_{52} x_{82} (t) + c_{52} x_{92} (t) + c_{52} x_{102} (t) + c_{52} x_{112} (t) \\
&+ c_{53} x_{63} (t) + c_{53} x_{73} (t) + c_{53} x_{83} (t) + c_{53} x_{93} (t) + c_{53} x_{103} (t) + c_{53} x_{113} (t) \\
&+ c_{54} x_{64} (t) + c_{54} x_{74} (t) + c_{54} x_{84} (t) + c_{54} x_{94} (t) + c_{54} x_{104} (t) + c_{54} x_{114} (t) \\
&+ c_{55} x_{65} (t) + c_{55} x_{75} (t) + c_{55} x_{85} (t) + c_{55} x_{95} (t) + c_{55} x_{105} (t) + c_{55} x_{115} (t) \\
&+ c_{56} x_{66} (t) + c_{56} x_{76} (t) + c_{56} x_{86} (t) + c_{56} x_{96} (t) + c_{56} x_{106} (t) + c_{56} x_{116} (t) \\
&+ c_{57} x_{67} (t) + c_{57} x_{77} (t) + c_{57} x_{87} (t) + c_{57} x_{97} (t) + c_{57} x_{107} (t) + c_{57} x_{117} (t) \\
&+ c_{58} x_{68} (t) + c_{58} x_{78} (t) + c_{58} x_{88} (t) + c_{58} x_{98} (t) + c_{58} x_{108} (t) + c_{58} x_{118} (t) \\
&+ c_{59} x_{69} (t) + c_{59} x_{79} (t) + c_{59} x_{89} (t) + c_{59} x_{99} (t) + c_{59} x_{109} (t) + c_{59} x_{119} (t) \\
&+ c_{60} x_{70} (t) + c_{60} x_{80} (t) + c_{60} x_{90} (t) + c_{60} x_{100} (t) + c_{60} x_{110} (t) \\
&+ c_{61} x_{71} (t) + c_{61} x_{81} (t) + c_{61} x_{91} (t) + c_{61} x_{101} (t) + c_{61} x_{111} (t) \\
&+ c_{62} x_{72} (t) + c_{62} x_{82} (t) + c_{62} x_{92} (t) + c_{62} x_{102} (t) + c_{62} x_{112} (t) \\
&+ c_{63} x_{73} (t) + c_{63} x_{83} (t) + c_{63} x_{93} (t) + c_{63} x_{103} (t) + c_{63} x_{113} (t) \\
&+ c_{64} x_{74} (t) + c_{64} x_{84} (t) + c_{64} x_{94} (t) + c_{64} x_{104} (t) + c_{64} x_{114} (t) \\
&+ c_{65} x_{75} (t) + c_{65} x_{85} (t) + c_{65} x_{95} (t) + c_{65} x_{105} (t) + c_{65} x_{115} (t) \\
&+ c_{66} x_{76} (t) + c_{66} x_{86} (t) + c_{66} x_{96} (t) + c_{66} x_{106} (t) + c_{66} x_{116} (t) \\
&+ c_{67} x_{77} (t) + c_{67} x_{87} (t) + c_{67} x_{97} (t) + c_{67} x_{107} (t) + c_{67} x_{117} (t) \\
&+ c_{68} x_{78} (t) + c_{68} x_{88} (t) + c_{68} x_{98} (t) + c_{68} x_{108} (t) + c_{68} x_{118} (t) \\
&+ c_{69} x_{79} (t) + c_{69} x_{89} (t) + c_{69} x_{99} (t) + c_{69} x_{109} (t) + c_{69} x_{119} (t) \\
&+ c_{70} x_{80} (t) + c_{70} x_{90} (t) + c_{70} x_{100} (t) + c_{70} x_{110} (t) \\
&+ c_{71} x_{81} (t) + c_{71} x_{91} (t) + c_{71} x_{101} (t) + c_{71} x_{111} (t) \\
&+ c_{72} x_{82} (t) + c_{72} x_{92} (t) + c_{72} x_{102} (t) + c_{72} x_{112} (t) \\
&+ c_{73} x_{83} (t) + c_{73} x_{93} (t) + c_{73} x_{103} (t) + c_{73} x_{113} (t) \\
&+ c_{74} x_{84} (t) + c_{74} x_{94} (t) + c_{74} x_{104} (t) + c_{74} x_{114} (t) \\
&+ c_{75} x_{85} (t) + c_{75} x_{95} (t) + c_{75} x_{105} (t) + c_{75} x_{115} (t) \\
&+ c_{76} x_{86} (t) + c_{76} x_{96} (t) + c_{76} x_{106} (t) + c_{76} x_{116} (t) \\
&+ c_{77} x_{87} (t) + c_{77} x_{97} (t) + c_{77} x_{107} (t) + c_{77} x_{117} (t) \\
&+ c_{78} x_{88} (t) + c_{78} x_{98} (t) + c_{78} x_{108} (t) + c_{78} x_{118} (t) \\
&+ c_{79} x_{89} (t) + c_{79} x_{99} (t) + c_{79} x_{109} (t) + c_{79} x_{119} (t) \\
&+ c_{80} x_{90} (t) + c_{80} x_{100} (t) + c_{80} x_{110} (t) \\
&+ c_{81} x_{91} (t) + c_{81} x_{101} (t) + c_{81} x_{111} (t) \\
&+ c_{82} x_{92} (t) + c_{82} x_{102} (t) + c_{82} x_{112} (t) \\
&+ c_{83} x_{93} (t) + c_{83} x_{103} (t) + c_{83} x_{113} (t) \\
&+ c_{84} x_{94} (t) + c_{84} x_{104} (t) + c_{84} x_{114} (t) \\
&+ c_{85} x_{95} (t) + c_{85} x_{105} (t) + c_{85} x_{115} (t) \\
&+ c_{86} x_{96} (t) + c_{86} x_{106} (t) + c_{86} x_{116} (t) \\
&+ c_{87} x_{97} (t) + c_{87} x_{107} (t) + c_{87} x_{117} (t) \\
&+ c_{88} x_{98} (t) + c_{88} x_{108} (t) + c_{88} x_{118} (t) \\
&+ c_{89} x_{99} (t) + c_{89} x_{109} (t) + c_{89} x_{119} (t) \\
&+ c_{90} x_{100} (t) + c_{90} x_{110} (t) \\
&+ c_{91} x_{101} (t) + c_{91} x_{111} (t) \\
&+ c_{92} x_{102} (t) + c_{92} x_{112} (t) \\
&+ c_{93} x_{103} (t) + c_{93} x_{113} (t) \\
&+ c_{94} x_{104} (t) + c_{94} x_{114} (t) \\
&+ c_{95} x_{105} (t) + c_{95} x_{115} (t) \\
&+ c_{96} x_{106} (t) + c_{96} x_{116} (t) \\
&+ c_{97} x_{107} (t) + c_{97} x_{117} (t) \\
&+ c_{98} x_{108} (t) + c_{98} x_{118} (t) \\
&+ c_{99} x_{109} (t) + c_{99} x_{119} (t) \\
&+ c_{100} x_{110} (t) + c_{100} x_{120} (t) \\
&+ c_{101} x_{111} (t) + c_{101} x_{121} (t) \\
&+ c_{102} x_{112} (t) + c_{102} x_{122} (t) \\
&+ c_{103} x_{113} (t) + c_{103} x_{123} (t) \\
&+ c_{104} x_{114} (t) + c_{104} x_{124} (t) \\
&+ c_{105} x_{115} (t) + c_{105} x_{125} (t) \\
&+ c_{106} x_{116} (t) + c_{106} x_{126} (t) \\
&+ c_{107} x_{117} (t) + c_{107} x_{127} (t) \\
&+ c_{108} x_{118} (t) + c_{108} x_{128} (t) \\
&+ c_{109} x_{119} (t) + c_{109} x_{129} (t) \\
&+ c_{110} x_{120} (t) + c_{110} x_{130} (t) \\
&+ c_{111} x_{121} (t) + c_{111} x_{131} (t) \\
&+ c_{112} x_{122} (t) + c_{112} x_{132} (t) \\
&+ c_{113} x_{123} (t) + c_{113} x_{133} (t) \\
&+ c_{114} x_{124} (t) + c_{114} x_{134} (t) \\
&+ c_{115} x_{125} (t) + c_{115} x_{135} (t) \\
&+ c_{116} x_{126} (t) + c_{
```

Inspect Variable Frequency Chart

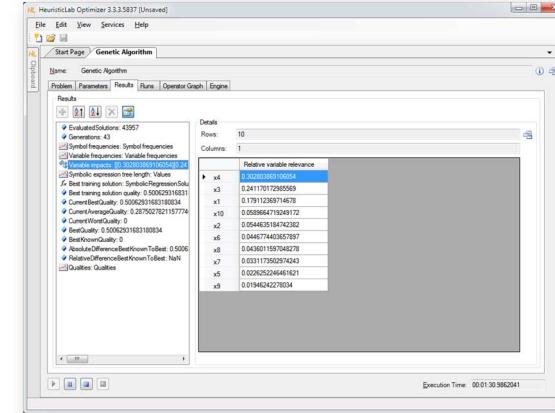


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Inspect Variable Impacts

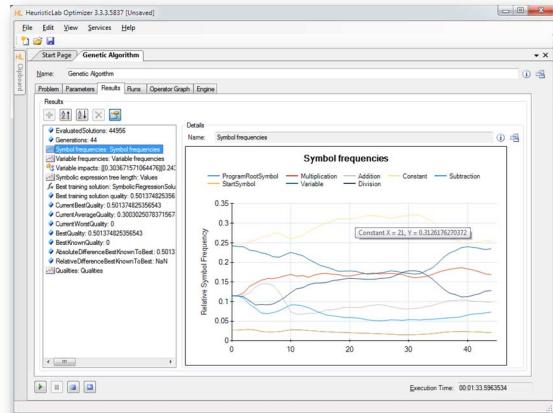


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Inspect Symbol Frequencies



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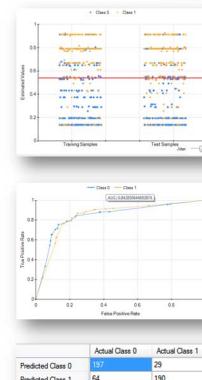
<http://dev.heuristiclab.com>

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Classification with HeuristicLab



- Symbolic classification
 - evolve discriminating function using GP
 - find thresholds to assign classes
- Demonstration
 - real world medical application
 - model accuracy
 - visualization of model output
 - discriminating function output
 - ROC-curve
 - confusion matrix



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Case Study: Classification



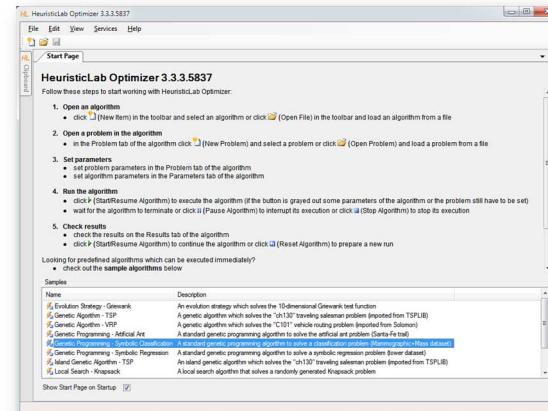
- Real world medical dataset (*Mammographic Mass*) from UCI Machine Learning Repository
 - data from non-invasive mammography screening
 - variables:
 - patient age
 - visual features of inspected mass lesions: shape, margin, density
 - target variable: severity (malignant, benign)
- download
<http://dev.heuristiclab.com/AdditionalMaterial#GECCO2012>

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Open Sample

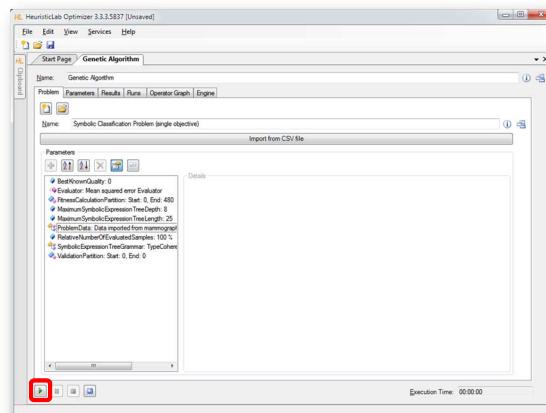


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Configure and Run Algorithm

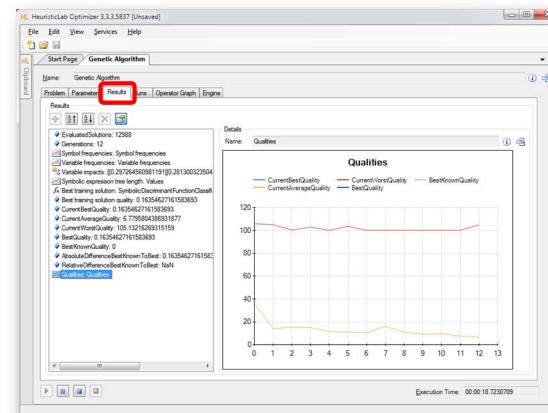


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Inspect Quality Linechart

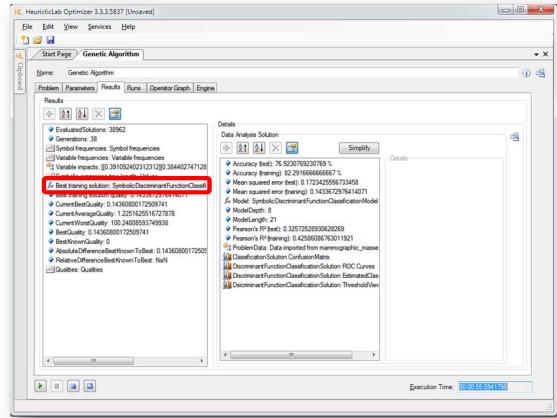


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Inspect Best Training Solution

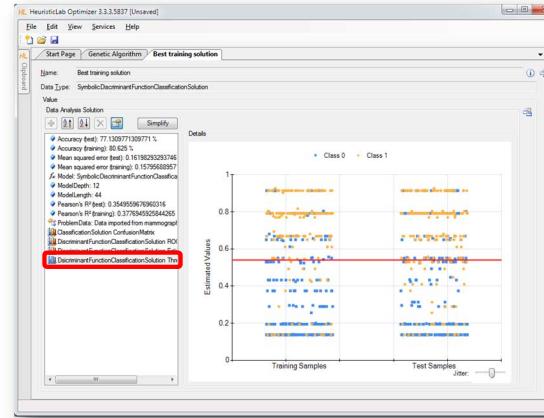


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Inspect Model Output and Thresholds

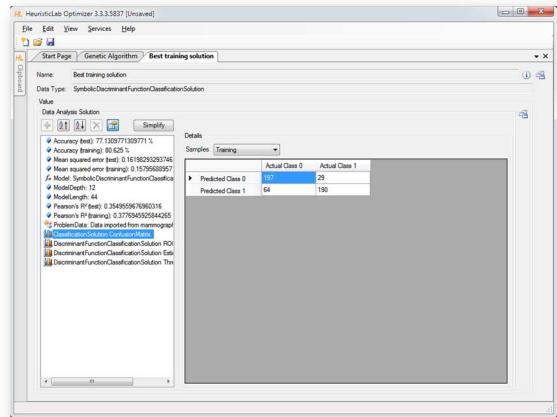


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Inspect Confusion Matrix

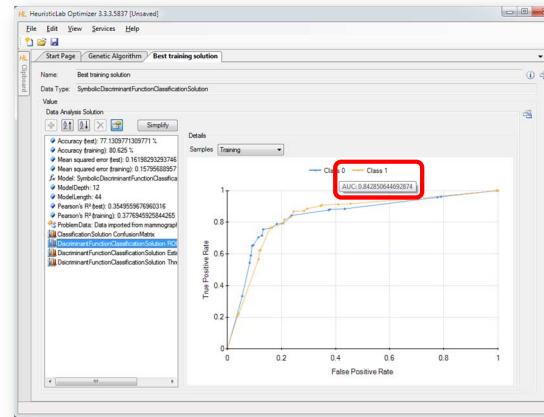


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Inspect ROC Curve



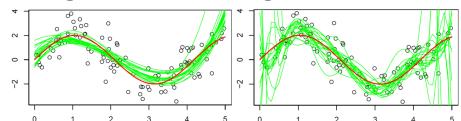
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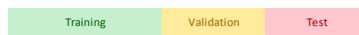
Validation of Results

- Overfitting = memorizing data

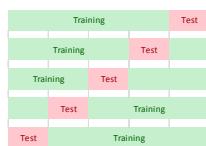


- Strategies to reduce overfitting

– validation partition



– cross-validation



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Validation of Results

- Demonstration

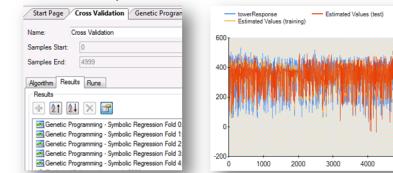
– Configuration of a validation set

– Inspection of best solution on validation set

– Analysis of training- and validation fitness correlation

- Cross-validation

- Configuration
- Analysis of results



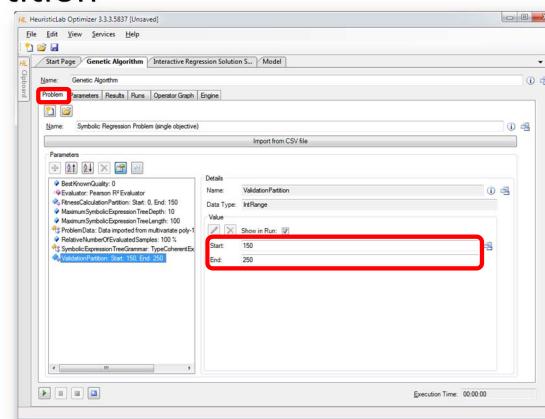
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Configuration of Validation Partition

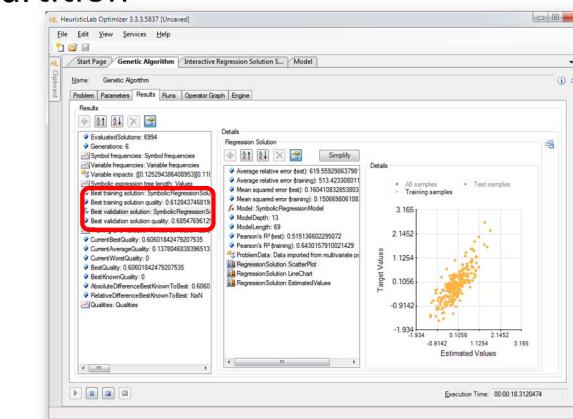


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Inspect Best Model on Validation Partition

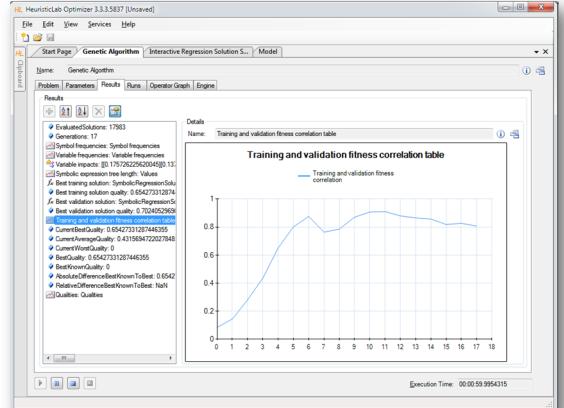


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Inspect Linechart of Correlation of Training and Validation Fitness



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Agenda

- Objectives of the Tutorial
- Introduction
- Where to get HeuristicLab?
- Plugin Infrastructure
- Graphical User Interface
- Available Algorithms & Problems
- **Demonstration Part I: Working with HeuristicLab**
- **Demonstration Part II: Data-based Modeling**
- Some Additional Features
- Planned Features
- Team
- Suggested Readings
- Bibliography
- Questions & Answers



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Some Additional Features

- HeuristicLab Hive
 - parallel and distributed execution of algorithms and experiments on many computers in a network
- Optimization Knowledge Base (OKB)
 - database to store algorithms, problems, parameters and results
 - open to the public
 - open for other frameworks
 - analyze and store characteristics of problem instances and problem classes
- External solution evaluation and simulation-based optimization
 - interface to couple HeuristicLab with other applications (MATLAB, AnyLogic, ...)
 - supports different protocols (command line parameters, TCP, ...)
- Parameter grid tests and meta-optimization
 - automatically create experiments to test large ranges of parameters
 - apply heuristic optimization algorithms to find optimal parameter settings for heuristic optimization algorithms



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Planned Features

- Algorithms & Problems
 - steady-state genetic algorithm
 - unified tabu search for vehicle routing
 - scatter search
 - ...
- Cloud Computing
 - port HeuristicLab Hive to Windows Azure
- Linux
 - port HeuristicLab to run on Mono and Linux machines
- Have a look at the HeuristicLab roadmap
 - <http://dev.heuristiclab.com/trac/hl/core/roadmap>
- Any other ideas, requests or recommendations?
 - join our HeuristicLab Google group heuristiclab@googlegroups.com or
 - write an e-mail to support@heuristiclab.com



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HeuristicLab Team



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Suggested Readings

- S. Voß, D. Woodruff (Edts.)
Optimization Software Class Libraries
Kluwer Academic Publishers, 2002



- M. Affenzeller, S. Winkler, S. Wagner, A. Beham
**Genetic Algorithms and Genetic Programming
Modern Concepts and Practical Applications**
CRC Press, 2009



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Springer, 2005
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Benefits of plugin-based heuristic optimization software systems
Computer Aided Systems Theory - EUROCAST 2007, Lecture Notes in Computer Science, vol. 4739, pp. 747-754
Springer, 2007
- S. Wagner, G. Kronberger, A. Beham, S. Winkler, M. Affenzeller
Modeling of heuristic optimization algorithms
Proceedings of the 20th European Modeling and Simulation Symposium, pp. 106-111
DIPTEM University of Genova, 2008
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Model driven rapid prototyping of heuristic optimization algorithms
Computer Aided Systems Theory - EUROCAST 2009, Lecture Notes in Computer Science, vol. 5717, pp. 729-736
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- S. Wagner
Heuristic optimization software systems - Modeling of heuristic optimization algorithms in the HeuristicLab software environment
Ph.D. thesis, Johannes Kepler University Linz, Austria, 2009.
- S. Wagner, A. Beham, G. Kronberger, M. Kommeda, E. Pitzer, M. Kofler, S. Vonolfen, S. Winkler, V. Dorfer, M. Affenzeller
HeuristicLab 3.3: A unified approach to metaheuristic optimization
Actas del séptimo congreso español sobre Metaheurísticas, Algoritmos Evolutivos y Bioinspirados (MAEB'2010), 2010
- Detailed list of all publications of the HEAL research group: <http://research.fh-ooe.at/de/orgunit/detail/356#showpublications>

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Questions & Answers



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