# BelVis PRO Enhancement Package (EHP)

## Sophisticated methods for superior forecasts

Methods for the highest quality of forecasts

Tools to hedge the model stability

Advanced Analysis Tools

Adaptation of information technology model criteria

KISTERS

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**Sophisticated methods for superior forecasts**

The BelVis PRO Enhancement Package (EHP) is based on the latest research and development from the KISTERS Modelling Department, and is now fully integrated in BelVis PRO. EHP adds the following to the already extensive functionality of BelVis PRO:

- New forecasting methods and optimised training algorithms, which significantly enhance the quality of forecasts and permit the shortest possible training times
- Cross-model tools, such as enhanced statistical evaluations and sensitivity analyses
- Optimised processes for ALN, e.g. stability analysis graphs, optimisation of the training data record length

# Forecasting Methods for Maximum Quality quality

**Recurrent Neural Networks (RNN)**

RNN may be utilised for the expansion of ALN and ANN models. The RNN is a data reservoir, which is fed from a variety of existing model inputs (vectors), and which can generate over 100 new model inputs. New vectors are fed into the RNN reservoir non-linearly, dampened and time-delayed with each time cycle. Data will therefore remain in the reservoir for an extended period of time, and may only become effective as model input many cycles later. The user specifies the number of new RNN inputs to be provided for the model as additional inputs, for example only 30, or over 100. An ALN will automatically assess the newly created inputs, and select only the useful ones. An ANN, on the other hand, will utilise and weigh all inputs.

RNN can be configured very easily in BelVis PRO EHP. The core is a visualisation of the adjacency matrix, which is specified by the internal data processing unit of the reservoir. A new random assignment is created at the touch of a button, and with it a new - and potentially better - modelling approach. Advanced users will be able to design the adjacency matrix in such a way as to assign specific properties to the reservoir.

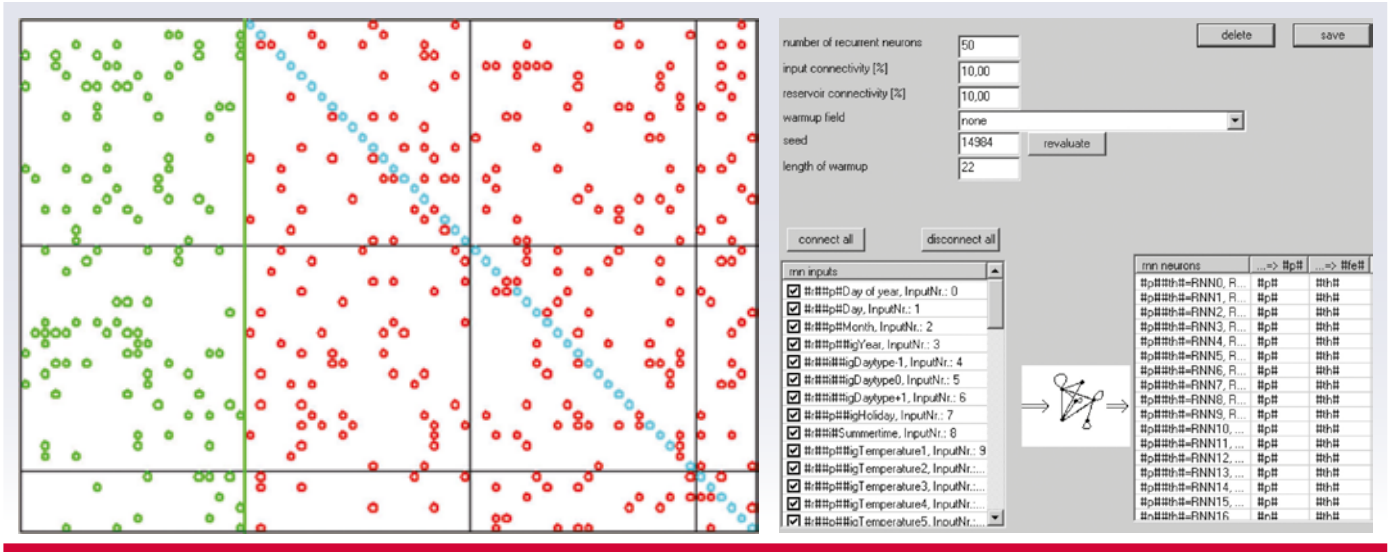



Figure: This adjacency matrix generates 50 new RNN inputs (blue) based on 27 model inputs (green).

Using RNN generates random and creative additions to the user's own modelling approach. It is quite amazing to see how random creativity can supplement own model formation efforts, thus enhancing the forecast quality.

### Hierarchical models

Hierarchical models facilitate a significant improvement of the forecast quality without the addition of new information. Several submodels (ALN, ANN, RNN, …) can be organised as a hierarchy through a simple drag & drop process. Only the uppermost model must be supplied with data, trained, and calculated. The specified training and calculation methods are then automatically applied to the submodels. BelVis PRO EHP offers three types of hierarchical models:

- Mean value based on n submodels (alternatively also median, maximum, minimum, …).
- Temporal sections (e.g. day, night, …) of the same problem are forecast based on separate submodels. The top model then assembles the partial forecasts in precise chronological order.
- Cascaded models use the submodel forecast outputs as input. The top model then carries out a refinement cycle of the submodel estimation. The estimated values from the submodels may be automatically replaced, specifically by recent online data, which offers more potential to improve the forecast quality.

All three variants may also be combined in turn inside hierarchical models. The optional optimisation of a hierarchical model automatically finds the best mix of all submodels, i.e. imprecise submodels are disabled.

### Innovative ANN training methods

BelVis PRO EHP offers a number of innovative ANN training methods, two of which have been submitted for patent consideration.

These methods facilitate automatic training, and automatic evaluation and optimisation of hidden neurons is now also possible.

The problem of rote learning when using too many hidden neurons is a typical weakness of non-professionally trained ANNs. BelVis PRO EHP prevents this from happening by specialised algorithms, even in cases with large numbers of hidden neurons. The resulting greater range of degrees of freedom for the model increases the attainable forecast quality.

Some training methods are based on special methods to conform to the error minimum in the multidimensional parameter space as closely as possible. A number of innovative approaches are employed to this end, including controlled model swarms.

Despite all these innovations, which present a significant algorithmic challenge, training times have been kept extremely short. The proverbial trip to the coffee machine is not longer necessary.

# Cross-Model Tools

## Statistical evaluations

A powerful statistical tool analyses the distribution of the forecast error and provides a graphical display. The empirical density function, with over 15 distribution functions, additionally allows you to approximate and specify the quality of the adjustment.

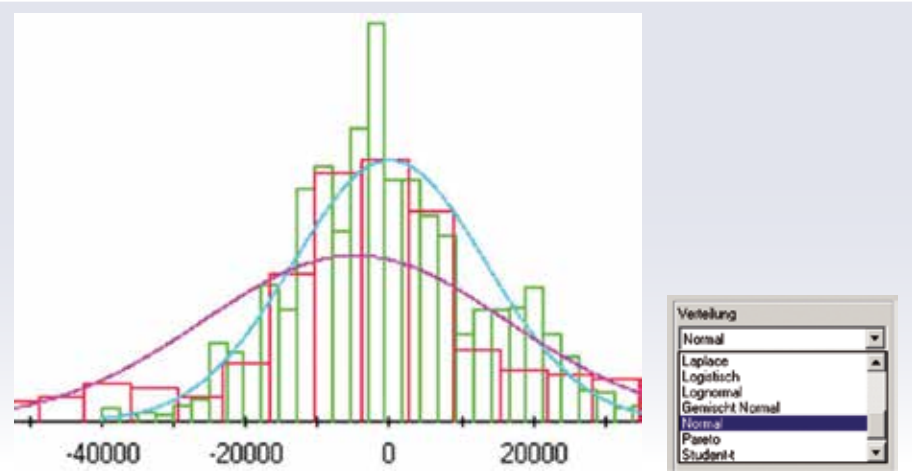



Figure: Density function of the error in the training and validation data range, with approximations

## Automatic determination of the value ranges

To ensure that the model can be trained correctly, it is necessary to specify the value range of the influencing variables and the values to be forecast as accurately as possible. Dynamic determination of the value range is particularly advantageous for models which are trained in cycles due to a continuously growing amount of historical data. Several parameterisation variants are available for this purpose in BelVis PRO EHP:

- Reset the value range
- Only extend the value range
- Define a tolerance within which the determined value range is extended
- Limit to specific inputs

Similarly, the value range of the model output is determined automatically prior to each training.

## Extended sensitivity analysis

An important modelling instrument is the autocorrelation of load and the correlation of influencing variables and the forecast error with the load.

BelVis PRO EHP shows the correlation of all influencing variables (with lag=0) in a bar graph available in the following variants:

- Correlation of the influencing variables at the input
- Correlation of the influencing variables „behind“ the pre-processing function split, i.e. at the so-called receptive fields
- Sensitivity analysis as a display of the load change in the case of maximum variation of the influencing variables within their value range

## Command dialog

The command dialog is used to run further operations on the models, e.g. extended error statistics for model assessment, preparation of an overview of the entire model parameter set (model status), model analyses, model optimisation, and CSV export of the training data set. The commands may be entered discretely and directly in the command dialog, or executed in sequence using batch files.

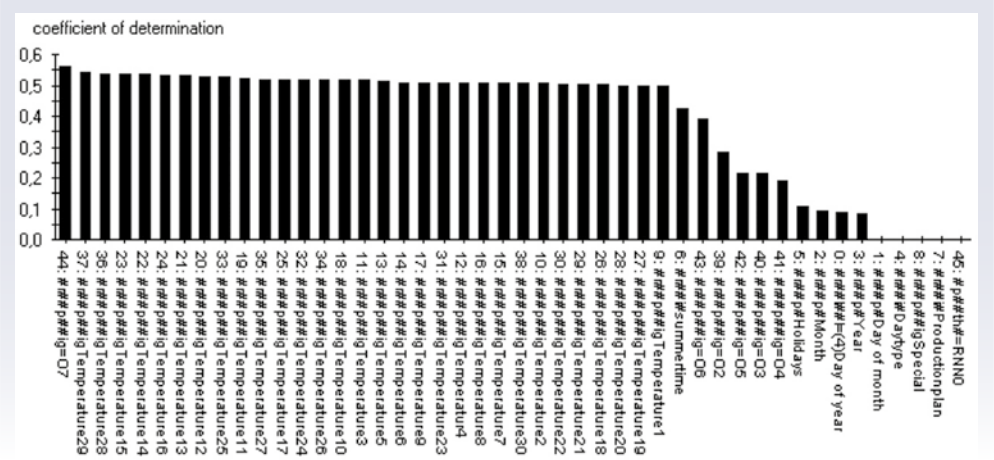



Figure: Coefficient of determination of the split inputs of an ALN model

## Logging

Training of very large models in optimisation mode (e.g. RNN, Recurrent Neural Networks with over 100 inputs) may take a while. The user is able to follow the log of the optimisation process using the command dialog, and can assume early control of the training result if the model error convergence is too weak. Critical processes and model parameters are also continuously logged in log files.

## Input cluster analysis

Input cluster analysis is an intelligent method of compiling a reduced yet representative training data set based on the entire range of available historical data. This also ensures that particularly important „young“ data is used as a foundation for training. This reorganisation of training data may be run as a preliminary step prior to each model training. BelVis PRO EHP includes a license for this limited use of cluster analysis. Comprehensive use of all cluster methods for other purposes is provided by BelVis CLUST.

# Optimised Procedures for ALN (Adaptive Logic Networks)

### Cross validation

The new cross validation procedure uses the entire data set for training. The youngest data, which is most characteristic for tomorrow's forecast, does not need to be sacrificed for model verification, resulting in the availability of more useful training data than usual. The procedure thus results in a more stable model by training a compromise for the full set of data.

### Input function optimisation

ALN facilitates automated modelling by disconnecting unnecessary influencing variables and „splitting" them with higher sensitivity. The splitting process couples inputs to the network with higher preprocessing functions. On command, BelVis PRO EHP optimises the selection of input functions and determines, specifically for each input, which function will provide the best forecast quality, e.g. a linear, power, Gaussian or sine function.

### Output characteristic optimisation

BelVis PRO also makes it possible to specify the output characteristic (transfer function of the output neurons) for an entire model (including linear, sigmoid, power). The output characteristic optimisation function in BelVis PRO EHP is executed on command and optimises each output neuron. As an example, this means that output neurons which provide night hour forecasts will be assigned a different temperature characteristic to day neurons.

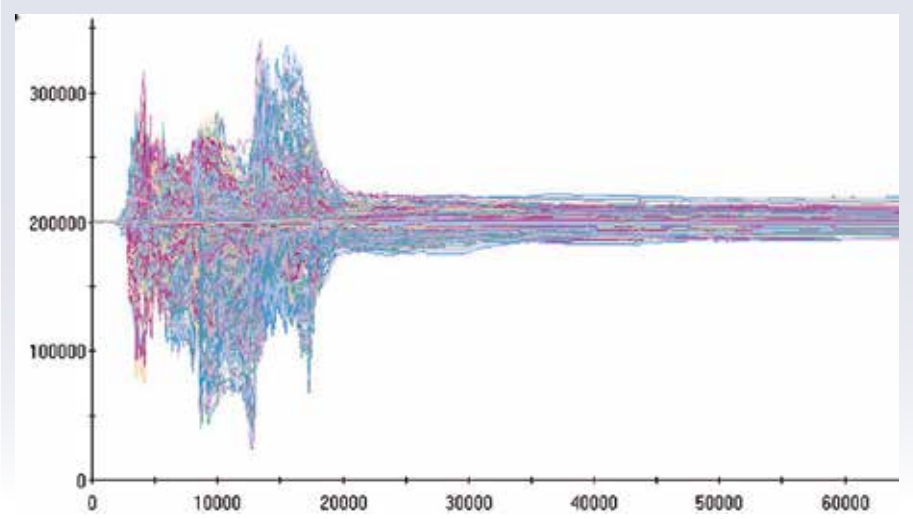



Figure: After approximately 20,000 15-minute training data records (208 days), the regression coefficients and therefore the model also are stable for the future.

### Optimization of the training data record length

An important method to optimise the quality of forecasts is the optimal determination of the record length of training data. If the history of training data is too short, the events that have to be learned by the model are not included completely yet. However, if the history is too long, the principles between the target values and the influencing values might have already changed.

The EHP tool „Rollling Analysis" simulates e.g. the daily forecast cycle with intermediate automated training / modeling. It logs the forecast error for each simulation step. By varying the training cycle, training history and information technology criteria, the tool helps to firgure out the optimal conditions.

### Tool for model stability analysis

It is typical to evaluate the quality of a model based on the error tested against a verification data set separate from the training data set. However, this is not necessarily meaningful in every case, because a good training result based on a random selection of training and verification data does not necessarily mean that a model will always deliver good forecasts.

For example if the verification data happens to represent a „properly forecast range", then the training result will appear to emulate a permanently good model. Or if the training data does not yet sufficiently cover the value ranges and combinations of influencing variables, the model will not necessarily deliver good forecasts in any case.

BelVis PRO EHP provides the user with both analysis methods to evaluate model stability, as well as comprehensive methods to stabilise the model.

Like a film, an animation clearly and understandably shows the development of training errors as a result of an increasing number of training data sets. The user can see how much training history is necessary to reach a stable forecast error over the following days, or permanently. A similar animation shows the model weight as a function of the training history. Stable weights across the entire range of available validation data indicates a stable model. „Weight outliers“ may be dampened manually to stabilise the model.

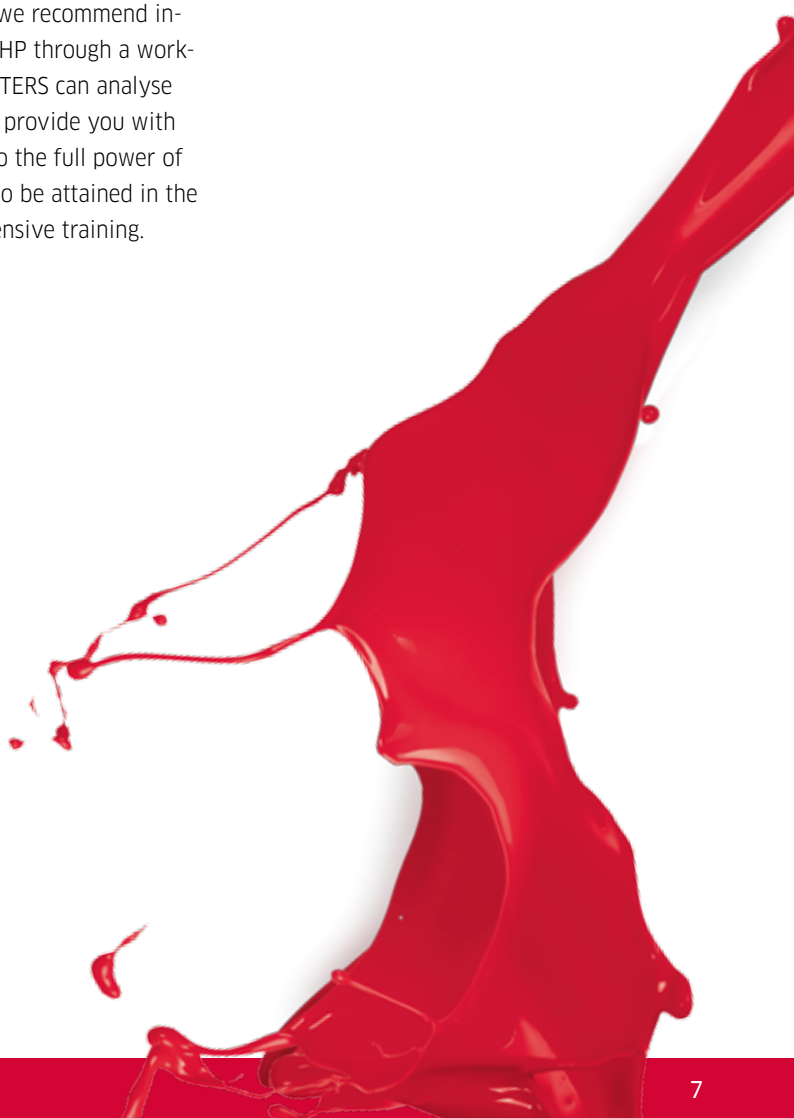
BelVis PRO EHP makes a range of parameterisable information criteria available in order to control model optimisation (splitting inputs to higher functions) so that each step in model quality optimisation is beneficial.

Furthermore, criteria also prevent rote learning of larger weightings, which may lead to localised inaccuracy in the forecast in the case of careless model configuration or as yet untrained constellations of input data. BelVis PRO EHP effectively reduces this fundamental problem.

# What Can Be Expected from BelVis PRO in the Future?

The KISTERS Modelling Department is continuously working on new concepts and research results, which will make BelVis PRO EHP even more powerful in the future. Cooperation agreements with universities also contribute to this process. Developments which allows users to create precise and stable forecasts, even without detailed forecasting knowledge and without much effort, also contribute to improvement of the standard version of BelVis PRO.

Due to its large scope, we recommend introducing BelVis PRO EHP through a workshop. Alternatively, KISTERS can analyse your requirements and provide you with ready-to-use models, so the full power of BelVis PRO EHP can also be attained in the short term without intensive training.



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