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Prognosen im Bereich erneuerbarer Energien auf Basis Neuronaler Netze

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Neural Networks @ Siemens: 24 Years of Research, Development, Innovation

Demand Forecasting

Load Forecasts for DB Energie

EEX EUROPEAN ENERGY EXCHANGE

Energy Price Forecasts

LME Copper Forecasts

Global Footprint Simulator

Clinical Trail Analysis

Quality Surveillance

Wind Turbines

Energy Mgt. for HEVs

Forecasting Transfer Losses

Solar Power

Gas Turbine Control

Economical Applications

Price Forecasting

Risk Analysis

Software Environment

Graphical User Interface

High Performance Computing

Demand Forecasting

Specification Languages

Prior Rule Information

State Space Modeling

Forecasting & Diagnosis

Scripted Modeling

Customer Relation Mgt.

Function Approximation

Complex Systems

Mathematics of

Neural Networks

Uncertainty Analysis

Feedforward Neural Nets

Decision Support

Learning Algorithms

Process Modeling

Data processing

Neuro-Fuzzy Networks

Recurrent Neural Nets

Optimal Control

Process Surveillance

Fuzzy Rules

Topology Design

for Neural Networks

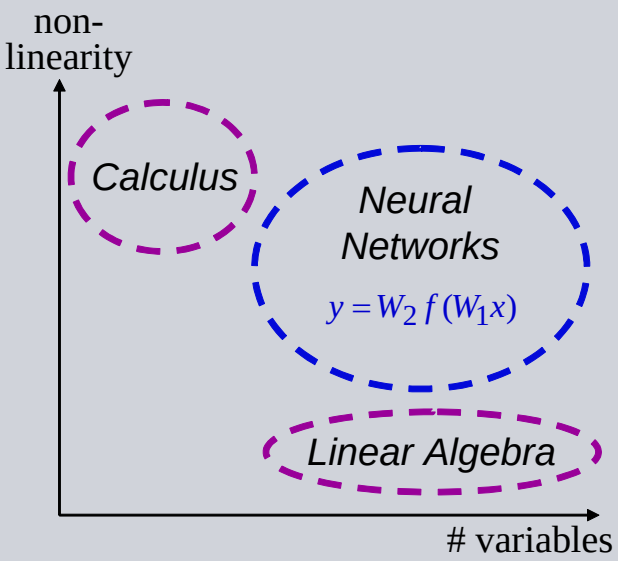
Forecasting Renewables

Process Control

Technical Applications

Mathematical Neural Networks

Complex Systems



Existence Theorem:
(Hornik, Stinchcombe, White 1989)

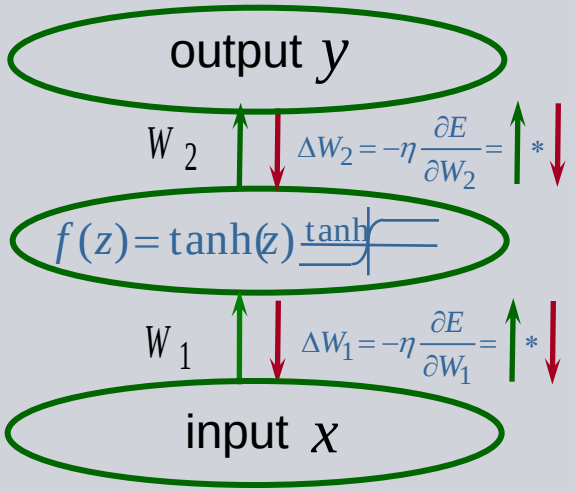
3-layer neural networks can approximate any continuous function on a compact domain.

Nonlinear Regression

Based on data identify an input-output relation

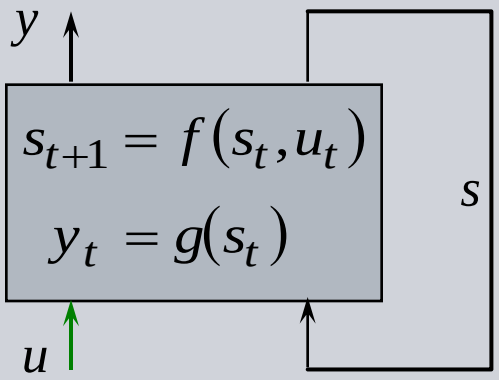
$$y = W_2 f(W_1 x)$$

$$\sum_{t=1}^{T} \left(y_t - y_t^d\right)^2 \rightarrow \min_{W_1, W_2}$$



Neural networks imply a **Correspondence** of ***Equations***, ***Architectures***, ***Local Algorithms***.

Modeling of Open Dynamical Systems with Recurrent Neural Networks (RNN)



$$s_{t+1} = \tanh\left(As_t + Bu_t\right) \quad \text{state transition}$$

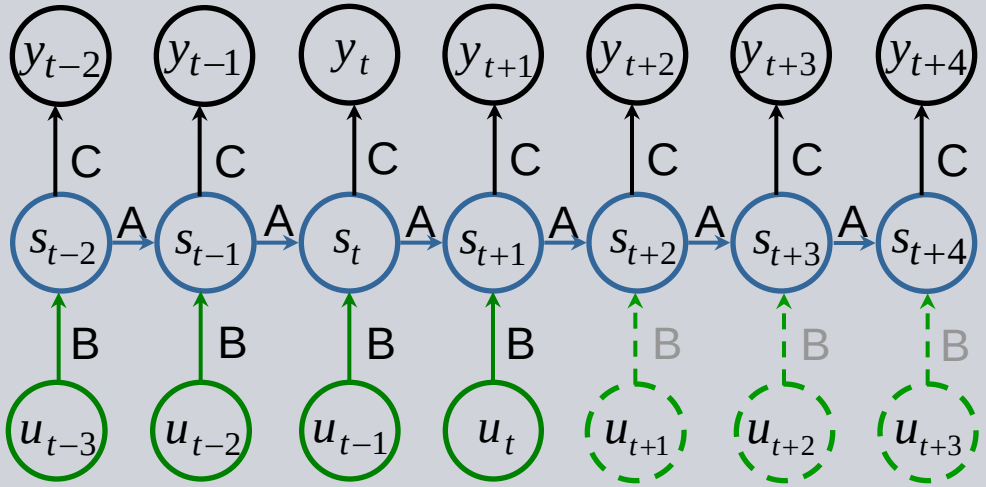
$$y_t = Cs_t \quad \text{output equation}$$

$$\sum_{t=1}^{T}\left(y_t - y_t^d\right)^2 \rightarrow \min_{A,B,C} \quad \text{identification}$$

Finite unfolding in time transforms time into a spatial architecture.

The analysis of open systems by RNNs allows a decomposition of its autonomous & external driven subsystems.

Long-term predictability depends on a strong autonomous subsystem.



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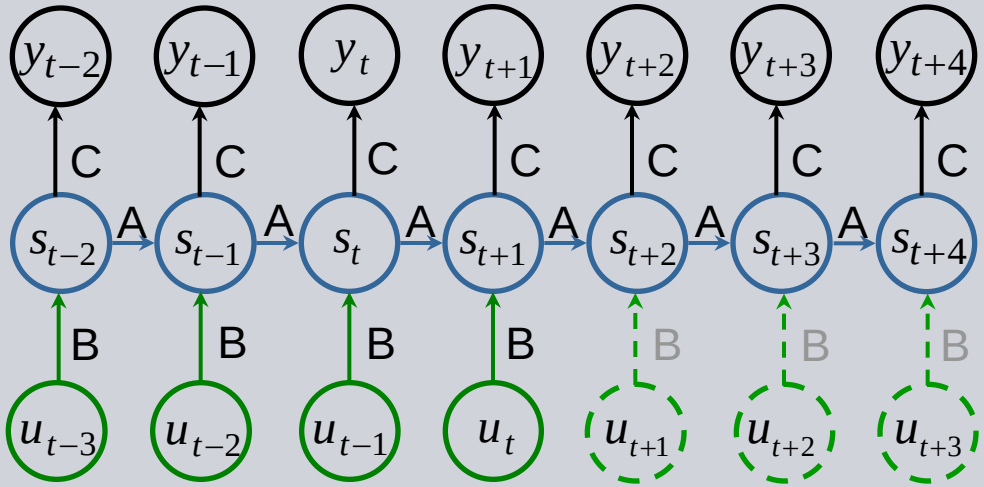
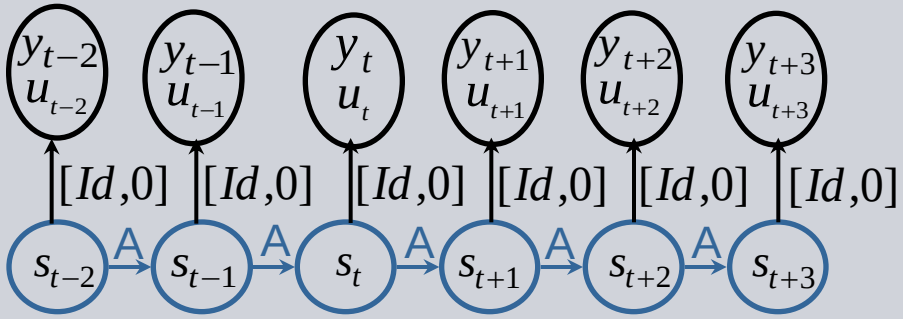
A Comparison between Open & Closed Systems



Small recurrent neural nets describe an input – output relationship over time. The open system is modeled as a superposition of an autonomous & an external driven subsystem. The concept works only in the frame of regression paradigms.

Large recurrent neural nets allow an embedding of the observables into a large state vector. These models are dynamical consistent, symmetric in all variables and present time does not play any special role.



Forecasting Solar Power Supply with Neural Networks (SENN*)

Ketura: Pilot PV plant for neural network (SENN) forecast model. SENN model will be integrated into the M3000 monitoring system

Problem Outline:

- Predict the energy supply of a solar farm based on ambient weather conditions (temperature and solar radiation)
- Forecast horizon is determined by the weather forecast
- Incorporation of physic based models and additional external influences (maintenance) are possible model extensions

Application Fields:

Accurate forecasts of the solar farm energy supply enable e.g.

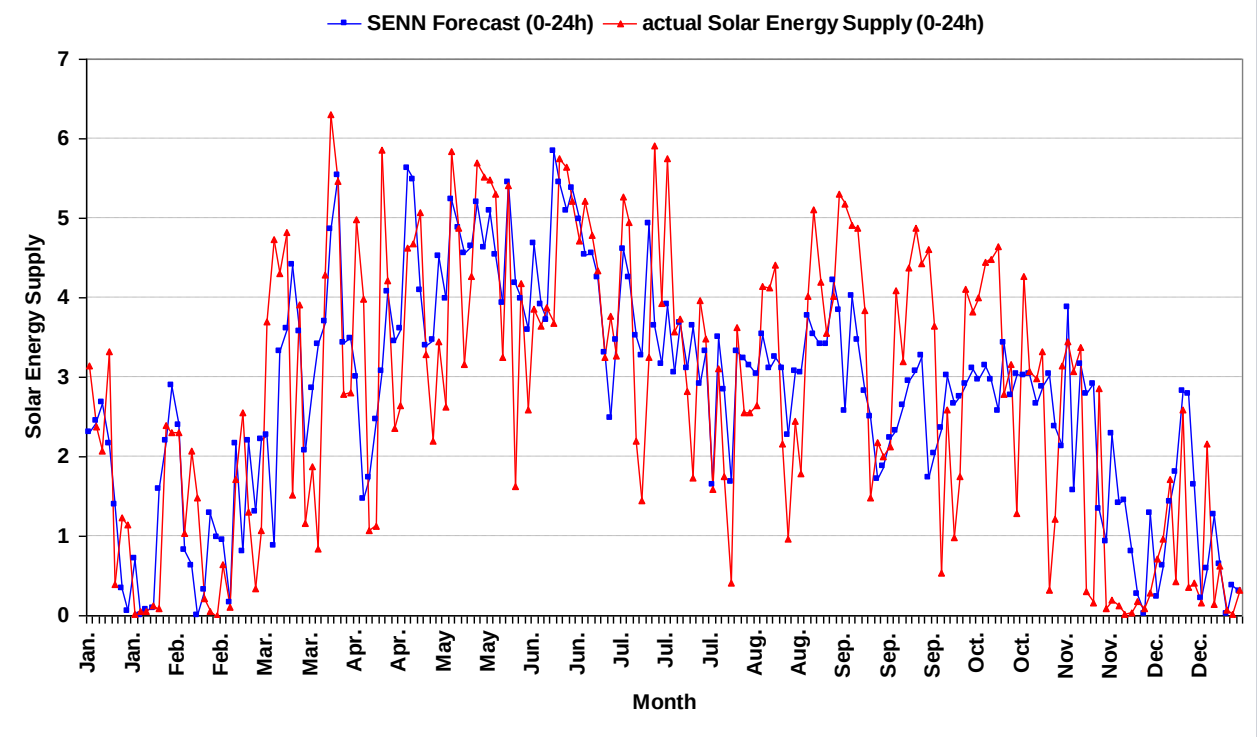
- the usage of solar power as an instantaneously available regulating energy source,
- the disposition of power quantities on the spot market,
- an optimal scheduling of maintenance jobs (soft sensor),
- the control of solar energy for an efficient grid management

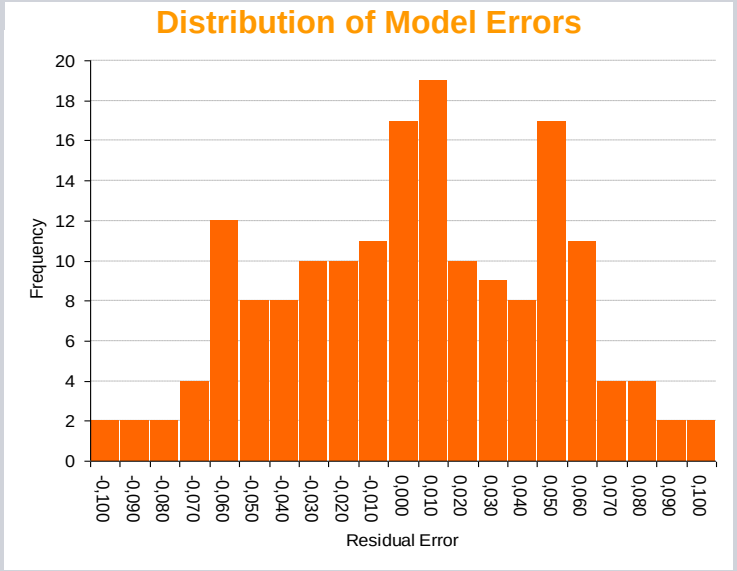
Solution:

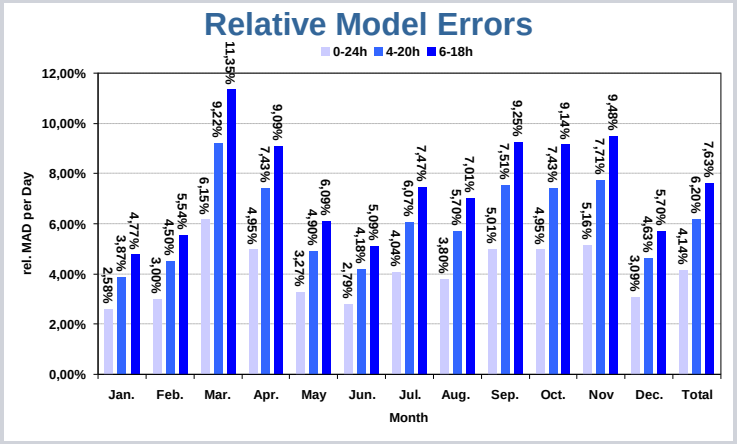
- Hybrid approach: Data driven modeling based on neural networks (SENN) in combination with a physics based model
- We explain the error of the physics based model with a neural network (SENN)

*SENN: Simulation Environment for Neural Networks

Neural Forecasting of Solar Power Supply

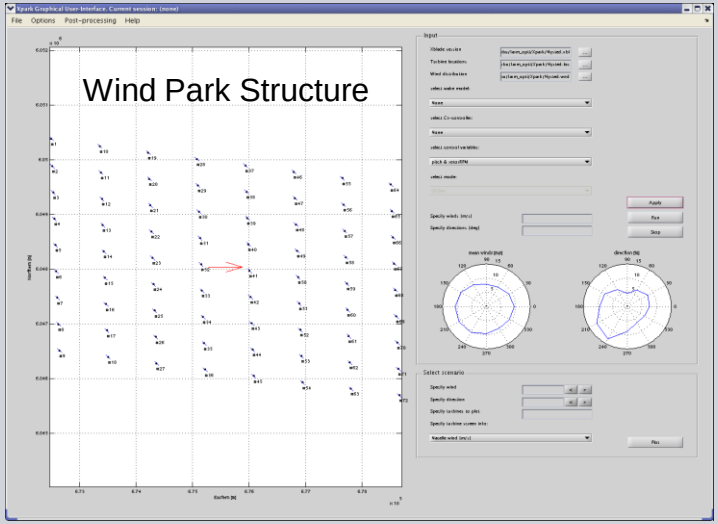






- **Task:** Forecast the solar energy supply of a PV plant over the next 24 hours
- **Solution:** Deep Neural Network (DNN) with 10 hidden layers. Inputs are weather data and forecasts (DWD)

Forecasting Wind Power Supply with Neural Networks



Problem Outline:

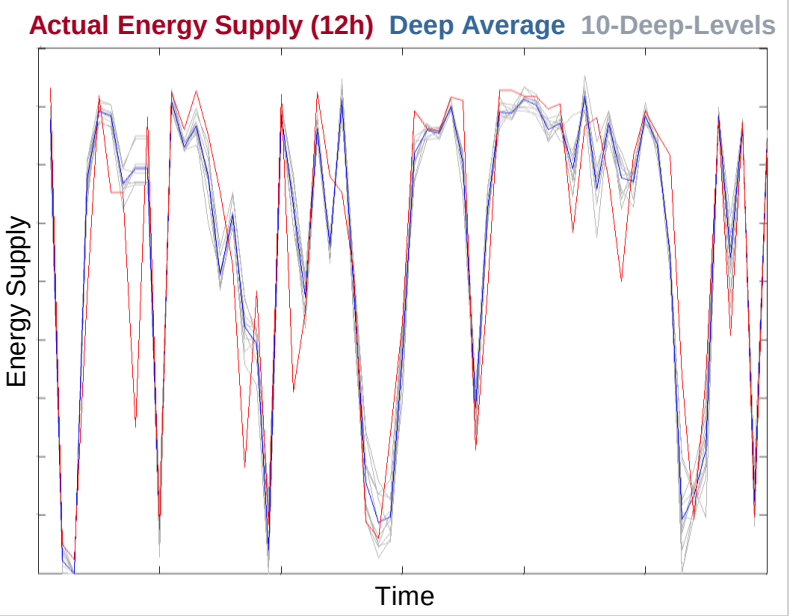
Accurate forecasts of the wind energy supply of an entire wind field enable e.g.

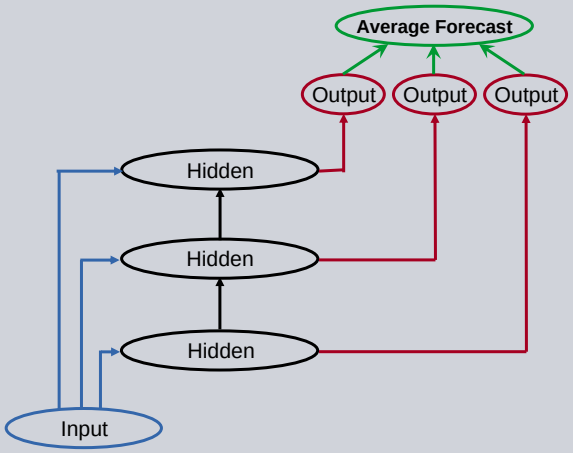
- the usage of wind power as an instantaneously available regulating energy source,
- the disposition of wind power quantities on the spot market (most beneficially in combination with an energy spot price prediction)
- an optimal scheduling of wind turbine maintenance jobs without losing too much wind park performance
- the control of the volatile energy resource and thus, an efficient power grid management
- also applicable for solar power energy supply

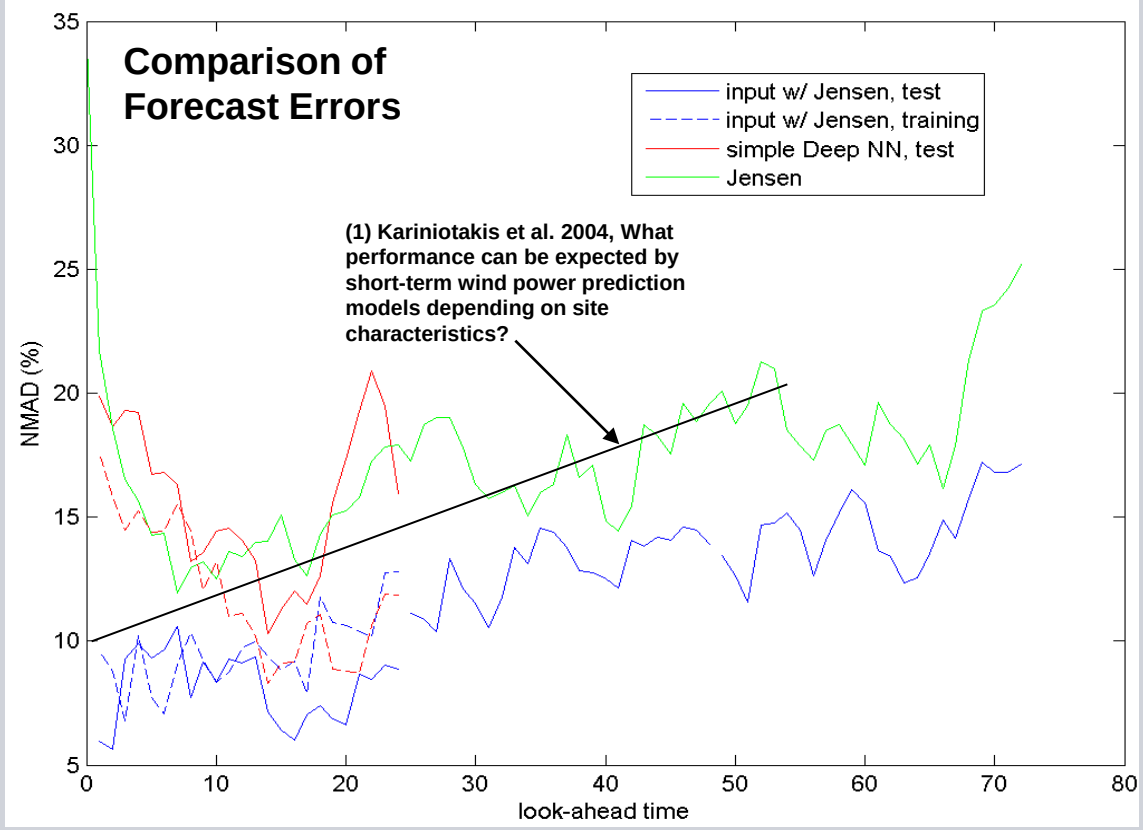
Solution Proposal:

Apply deep neural networks to forecast the energy supply of the entire wind field in short-term (i.e. up to 1 day in e.g. 1 hour buckets).

Neural Forecasting of Wind Power Supply





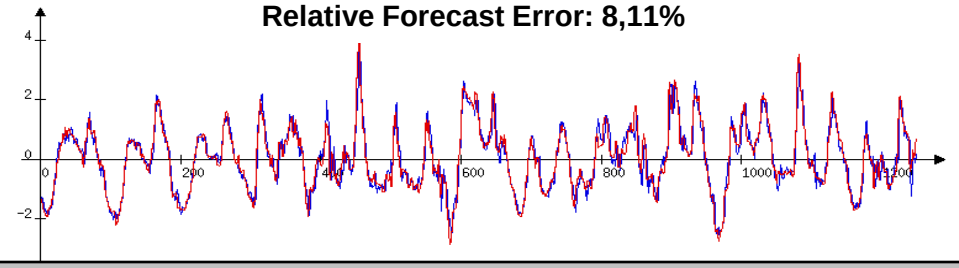


- Deep Neural Network delivers best performance
- Performance comparable to Jensen model
- **When results of Jensen model is provided as additional input the performance of the Deep NN is significantly improved**

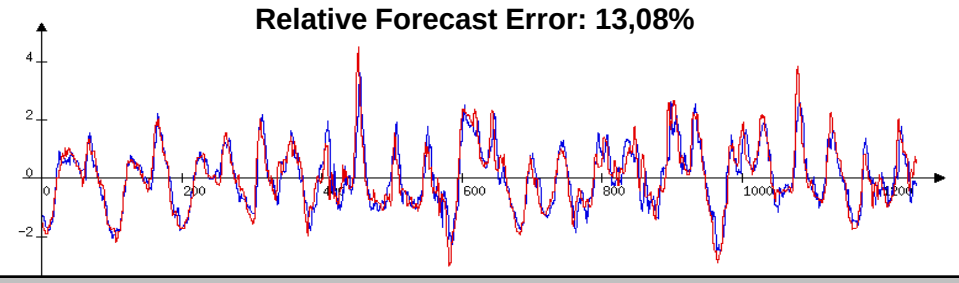
Forecasting of Energy Exchange between Control Areas

- Prediction of energy exchange between energy control areas to optimize energy balancing
- First experiences with net-interchange forecasting from project with US customer
- ECNN outperforms benchmarks: 120 min. error for MLP **29,44%** and linear regression **27,96%**

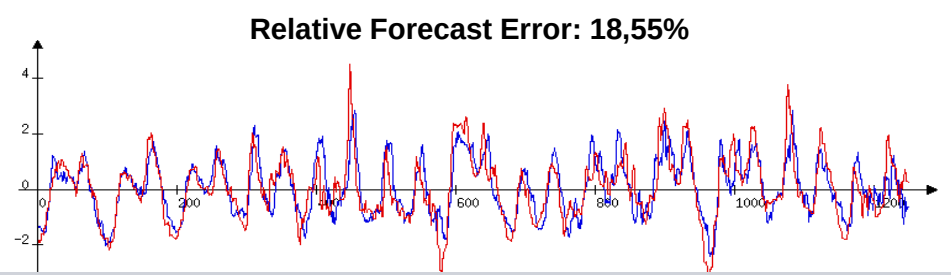
30 min. Net-Inter-Change Forecast: Model Output vs. Target



60 min. Net-Inter-Change Forecast: Model Output vs. Target

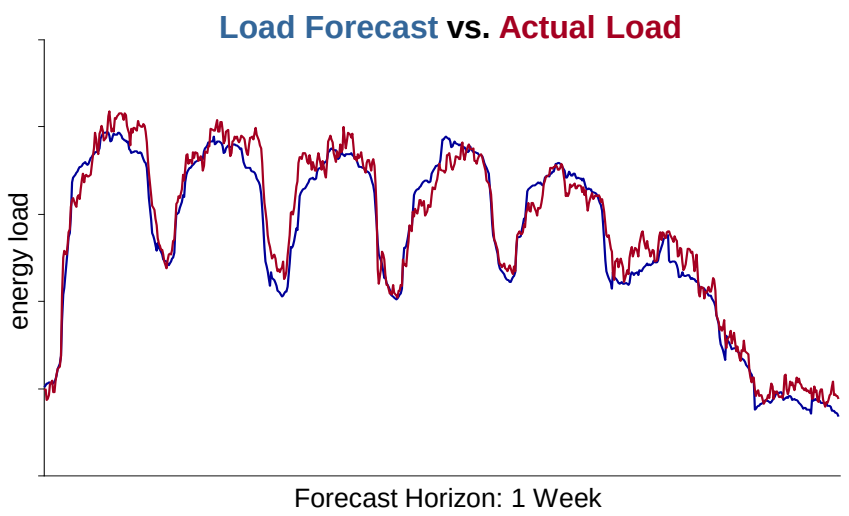


120 min. Net-Inter-Change Forecast: Model Output vs. Target



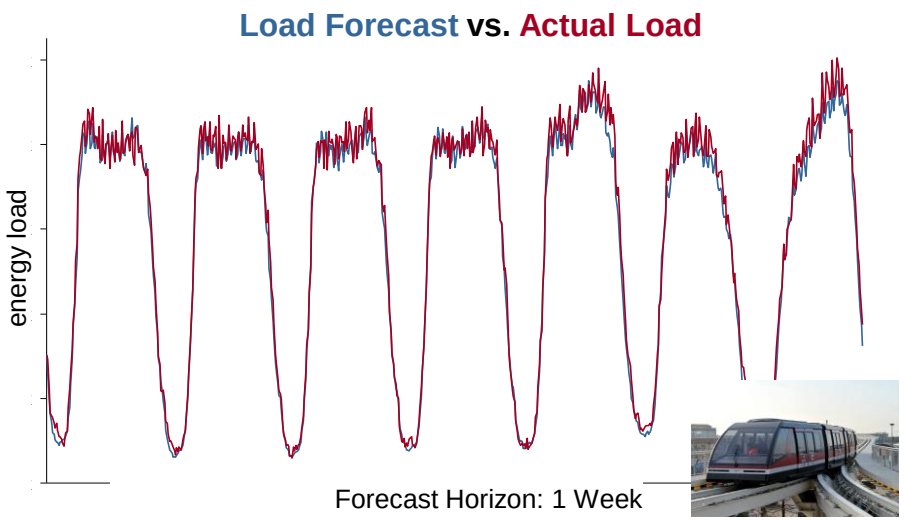
Electrical Energy Load Forecasting

Load Forecasting for the Industry Sector



Accuracy of load forecast is 96.15% (Benchmark 90%)

Load Forecasting for the Logistic Sector



Accuracy of load forecast is 97,95% (Benchmark 95%)

- **Task:** Predict the upcoming energy demand on a 15 min. time grid up to 5 days ahead.
- **Difficulties:** Incorporate the impact of external influences on the energy demand.
- **Solution:** Recurrent neural networks represent the load curve of each day by a superposition of intraday structure. Forecast models are embedded into SENN.

EEX Energy Future Price Predictions


Wir in Deutschland

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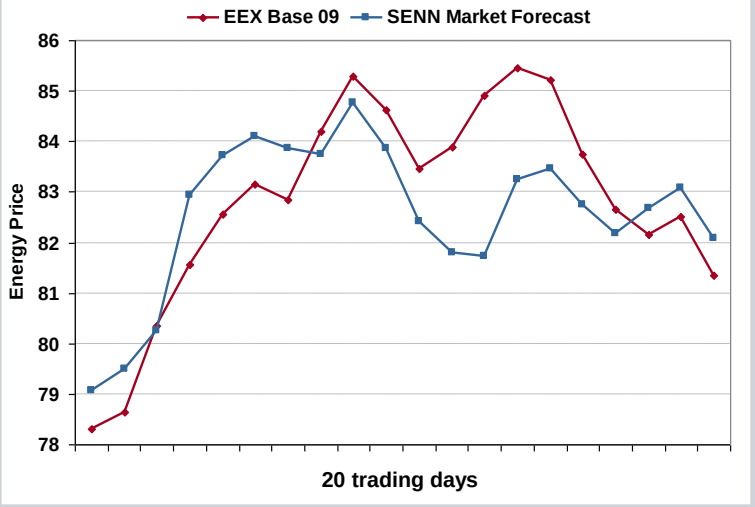
Bündeln und sparen

Bündeln und sparen

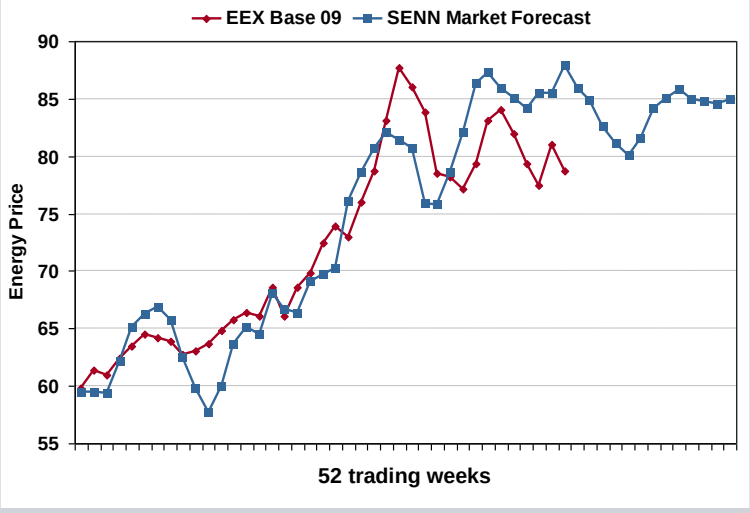
Stromeinkauf erfolgt bei Siemens zentral über die CSP für alle Standorte und Beteiligungsgeschaften

… Wertvolle Hilfe gibt seit fast zwei Jahren außerdem eine Abteilung von Corporate Technology (CT), die sich mit der Entwicklung von Prognosemodellen beschäftigt. Dazu erklärt Hans Georg Zimmermann (CT IC 4): „Wir hier im Fachzentrum Learning Systems beschäftigen uns damit, wie wir mit Hilfe Neuronaler Netze und einer speziellen Software Strompreisprognosen erstellen können. Das hilft, Risiken zu minimieren und Marktchancen zu nutzen.“ Um den Strombörsenpreis für die nächsten 20 Tage zu ermitteln, rechnet der Computer mehrere Szenarien durch, was eine ganze Nacht lang dauert. Mit gutem Erfolg: die Trefferquote liegt bei bis zu 80 Prozent.

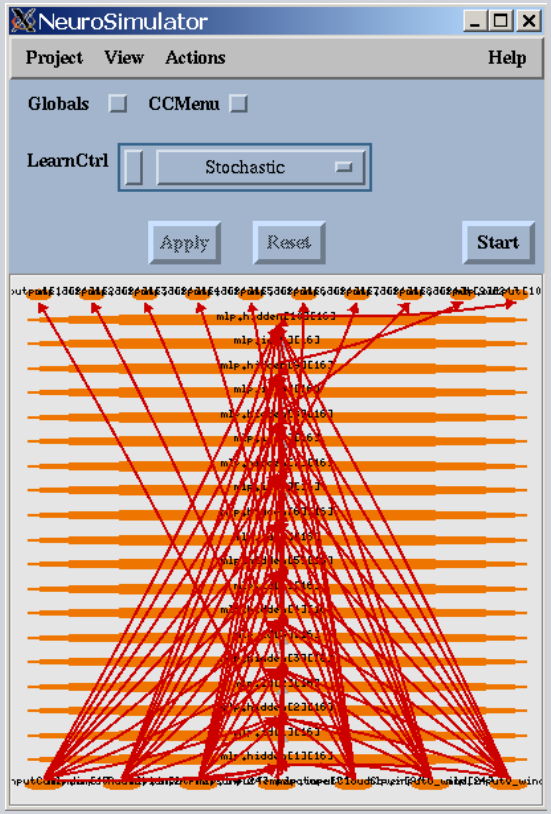
20-Days Energy Price Forecast



52-Weeks Energy Price Forecast



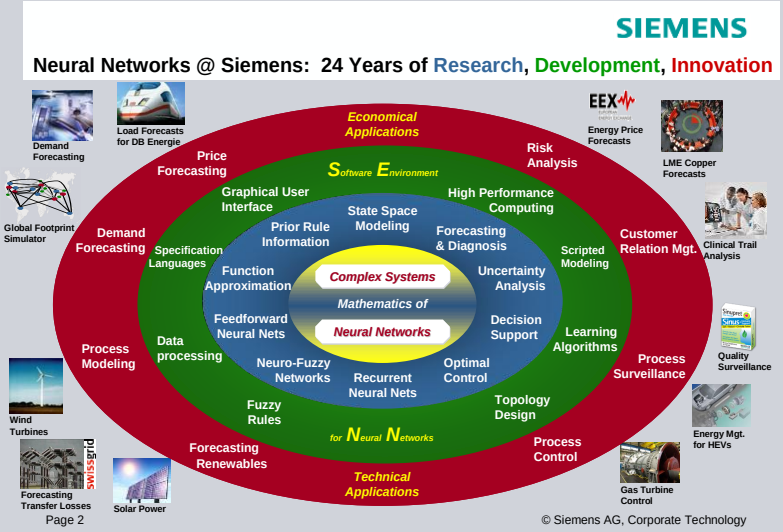
Simulation Environment for Neural Networks (SENN)



SENN merges 22-years of research and project experience in NN algorithms and architectures for industrial and economical applications

- SENN is a platform for the creation of neural network based forecasting, diagnosis, classification and control models
- SENN also includes methods & algorithms for an analytical interpretation and analysis of the neural network results
- SENN incorporates a broad spectrum of NN architectures:
  - Feedforward networks for soft sensors and classification
  - Neuro-Fuzzy networks for rule- and data-based modeling
  - Small recurrent networks for modeling dynamical systems
  - Large recurrent models for modeling interacting dynamics
- SENN models can be exported as XML description or C-code description A separate Java run-time-system allows to operate the models on different platforms
- Automated model building, training and analysis based on a TCL-script interface or remotely over a network interface
- SENN is supported on Linux and Solaris as well as Windows

Neural Networks: Range of Offers



Research and Development

- Development of individual forecast solutions and decision support systems based on state-of-the-art neural networks

Consulting and Development Support

- Consulting, design and development support for forecast, diagnosis and decision support systems
- Improvement of existing systems

Application Service Providing

- Design, build and maintain forecast models for customers
- Operate forecast models for customers
- IT integration of forecast models into customer environment

Software Licenses

- Licensing of advanced machine learning and neural network platforms
- Prototype models, training, maintenance, IT integration

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