Business Forecasting with Artificial Neural Networks

IBF Tutorial 2004 – Institute of Business Forecasting
Boston, August 5th 2004

Sven F. Crone
University of Hamburg, Institute of Information Systems
Lancaster University Management School, Centre for Forecasting
E-Mail: crone@bis-lab.com

What you may expect from this session ...

- Simple back propagation algorithm [Rumelhart et al. 1982]

⇒ „How to …“ on Neural Network Forecasting without Maths!

⇒ CD-Start-Up Kit for Neural Network Forecasting
   → 20+ software simulators
   → datasets
   → literature & faq

⇒ slides, data & additional info on:
www.bis-lab.de/IBF2004.htm
www.neural-forecasting.com

E-mail: crone@bis-lab.com
Research & Consultant-Profile: Sven F. Crone

Position: Senior Consultant  
Nationality: German  
Born: 1971

Languages

- German  
- English

Education

2004  
Post Doc Researcher at Int. Centre for Forecasting, Lancaster University, UK

2003  
Research Fellow at the George Mason Uni, USA

2003  
Visiting Scientist at the Stellenbosch Business School, USB, South Africa.

2000-2004  
Research & Teaching Assistant University of Hamburg, PhD-thesis on Forecasting in Inventory Management using ANN

1992-1997  
University of Hamburg  
MBA equiv. (Dipl.-Kfm.) in Business Administration

Work Experience

2004 - …  
Research Associate, Lancaster University, United Kingdom

2000-2004  
Research & Teaching Assistant University of Hamburg, Prof. Preißmar & Voß; Various projects in industry & trade

1996-2000  
CEO RSG Software GmbH, Management & IT-Consultant for Retail & Wholesale Projects in Germany & UK & Hungary.

Key-Projects

- Forecasting Methods in SAP APO-DP, bdf HAM, Sales Forecast Management & bdf Netherlands
- Automatic Model Selection in APO-DP, bdf HAM, Sales Forecast Management
- Sales Forecasts, AOK/TimeWamer, GfK
- Forecasting for Customer Relationship Management, Grün & Jahr AG, GER
- Implementing a Forecast Strategy & Inventory Management in Vending Supply Chain, Mayfair Services, UK
- Inventory Management in Distributions-Center Logistics, Vendepac, UK

Method Competency

- SAP APO  
- SAP Curriculum PLM100, SCM200, SCM 220  
- Inventory Management  
- Forecasting methods  
- Inventory Management  
- Supply Chain Planning/ APS  
- Warehouse logistics  
- Distribution / Supply logistics  
- Business Information Systems

Problem Competency

- Demand Planning in Consumer Goods Industry  
- Demand Planning in Retail & Wholesale
- Member of the IFB Institute of Business Forecasters  
- Member of the International Institute of Forecasters IIF  
- Member of IEEE; GOR, GI, ORSA ...
- Regular Presentations at ANN conferences of IEEE, INNS, APNNA

Sven F. Crone  
Tel. +49.171.4910100  
eMail: crone@bis-lab.de  
Internet: www.bis-lab.de
Research & Corporate Projects – B I³S Lab

Hamburg University: Institute of Information Systems
Lancaster University: Management Centre for Forecasting

- Core Competencies
  - Method competency: Forecasting & AI (Neural Nets, EA ...)
  - Software competency: SAP APO DP, Finmatica, Forecast Pro ...
- Services (Non Profit!)
  - Consultancy (→ process analysis, unbiased software selection etc.)
  - Research (→ prototype software, new application domains etc.)
  - Coaching (→ forecasting courses from Exp.Smooth to Neural Nets)
- Forecasting competency: member / tutor

Selected references:

Agenda

Business Forecasting with Artificial Neural Networks

1. Introduction to Neural Networks
   a. Definition
   b. Preview: Online Simulation of Neural Network Forecasting
   c. Neural Networks role in CORPORATE BUSINESS forecasting
   d. Motivation & brief history of Neural Networks
   e. From biological to artificial Neural Network Structures
   f. Network Training
2. Application of Neural Networks to Business Forecasting
3. Hands-on exercises in Neural Networks forecasting
4. Tips & Tricks for Improving Neural Networks based forecasts
5. Questions & Answers and Discussion
What are Artificial Neural Networks?

- Artificial Neural Networks (NN)
  - "a machine that is designed to model the way in which the brain performs a particular task ...; the network is ... implemented ... or ... simulated in software on a digital computer." [Haykin88]
  - class of statistical methods for information processing consisting of large number of simple processing units (neurons), which exchange information of their activation via directed connections. [Zell97]

![Diagram of Neural Network](image)

Demonstration: Preview of Neural Network Forecasting

- Simulation of NN in Business Forecasting with NeuroPredictor

- Airline Passenger Data Experiment
  - 3 layered NN: (12-8-1) 12 Input units - 8 hidden units - 1 output unit
  - 12 input lags t, t-1, ..., t-11 (past 12 observations) → time series prediction
  - t+1 forecast → single step ahead forecast

- Benchmark Time Series
  - [Brown / Box&Denkins]
  - 132 observations
  - 13 periods of monthly data
Demonstration: Preview of Neural Network Forecasting

Agenda

Business Forecasting with Artificial Neural Networks

1. Introduction to Neural Networks
   a. Definition
   b. Preview Simulation of Neural Network Forecasting
   c. Neural Networks role in CORPORATE BUSINESS forecasting
   d. Motivation & brief history of Neural Networks
   e. From biological to artificial Neural Network Structures
   f. Network Training

2. Application of Neural Networks to Business Forecasting

3. Hands-on exercises in Neural Networks forecasting

4. Tips & Tricks for Improving Neural Networks based forecasts

5. Questions & Answers and Discussion
Applications of Neural Nets in diverse Research Fields

- Neurophysiology
  - simulate & explain brain
- Informatics
  - eMail & URI filtering
- Speech Recognition & Optical Character Recognition
- Engineering
  - control applications in plants
  - automatic target recognition (DARPA)
- Meteorology / weather
  - Rainfall prediction
- Corporate Business
  - credit card fraud detection
  - simulate forecasting methods
- Different Forecasting Domains
  - Electrical Load / Demand
  - Financial Forecasting
    - Currency / Exchange rate
    - stock forecasting etc.
  - Sales forecasting
- not all NN recommendations are useful for your DOMAIN!

Citation Analysis by year

- Citation Analysis by year
- NN and forecasting related point predictions
- $R^2 = 0.9036$

Number of Publications by Business Forecasting Domain

- General Business
- Marketing
- Finance
- Production
- Product Sales
- Electrical Load
- Electrical Load

Different model classes of Neural Networks

- Since 1960s a variety of NN were developed for different tasks
  - Classification + Optimization + Forecasting → Application Specific Models

Different CLASSES of Neural Networks for Forecasting alone!
- Focus only on original Multilayer Perceptrons!
IBF Benchmark—Forecasting Methods used

Applied Forecasting Methods (all industries)

- Averages
- Autoregressive Methods
- Decomposition
- Exponential Smoothing
- Trend extrapolation
- Econometric Models
- Neural Networks
- Regression
- Analogies
- Delphi
- PERT
- Surveys

- Time Series methods (objective) → 61%
- Causal Methods (objective) → 23%
- Judgemental Methods (subjective) → 2x%

Survey 5 IBF conferences in 2001
240 forecasters, 13 industries

NN are applied in corporate Demand Planning / S&OP processes!
(Warning: limited sample size)

Agenda

Business Forecasting with Artificial Neural Networks

1. Introduction to Neural Networks
   a. Definition
   b. Preview Simulation of Neural Network Forecasting
   c. Neural Networks role in CORPORATE BUSINESS forecasting
   d. Motivation & brief history of Neural Networks
   e. From biological to artificial Neural Network Structures
   f. Network Training
2. Application of Neural Networks to Business Forecasting
3. Hands-on exercises in Neural Networks forecasting
4. Tips & Tricks for Improving Neural Networks based forecasts
5. Questions & Answers and Discussion
Motivation for using NN ... BIOLOGY!

- Human & other nervous systems (animals, insects \(\rightarrow\) e.g. bats)
  - Ability of various complex functions: perception, motor control, pattern recognition, classification, prediction etc.
  - Speed: e.g. detect & recognize changed face in crowd=100-200ms
  - Efficiency etc.
- Brains are the most efficient & complex computer known to date

<table>
<thead>
<tr>
<th></th>
<th>Human Brain</th>
<th>Computer (PCs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Processing Speed</td>
<td>(10^{-3})ms (0.25 MHz)</td>
<td>(10^{-9})ms (2500 MHz PC)</td>
</tr>
<tr>
<td>Neurons/Transistors</td>
<td>10 billion &amp; (10^3) billion conn.</td>
<td>50 million (PC chip)</td>
</tr>
<tr>
<td>Weight</td>
<td>1500 gr</td>
<td>kg to tons!</td>
</tr>
<tr>
<td>Energy consumption</td>
<td>(10^{-16}) Joule</td>
<td>(10^{-6}) Joule</td>
</tr>
<tr>
<td>Computation: Vision</td>
<td>100 steps</td>
<td>billions of steps</td>
</tr>
</tbody>
</table>

Comparison: Human = 10,000,000,000 \(\rightarrow\) ant 20,000 neurons

Brief History of Neural Networks

- History
  - Developed in interdisciplinary Research (McCulloch/Pitts 1943)
  - Motivation from Functions of natural Neural Networks
    - neurological motivation
    - application-oriented motivation

- Research field of Soft-Computing & Artificial Intelligence
  - Neuroscience, Mathematics, Physics, Statistics, Information Science, Engineering, Business Management
  - different VOCABULARY: statistics versus neurophysiology !!!
Dictionary for Neural Network Terminology

- Due to its neuro-biological origins, NN use specific terminology

<table>
<thead>
<tr>
<th>Neural Networks</th>
<th>Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Nodes</td>
<td>Independent / lagged Variables</td>
</tr>
<tr>
<td>Output Node(s)</td>
<td>Dependent variable(s)</td>
</tr>
<tr>
<td>Training</td>
<td>Parameterization</td>
</tr>
<tr>
<td>Weights</td>
<td>Parameters</td>
</tr>
</tbody>
</table>

→ don't be confused: ASK!

Agenda

Business Forecasting with Artificial Neural Networks

1. Introduction to Neural Networks
   a. Definition
   b. Preview Simulation of Neural Network Forecasting
   c. Neural Networks role in CORPORATE BUSINESS forecasting
   d. Motivation & brief history of Neural Networks
   e. From biological to artificial Neural Network Structures
   f. Network Training
2. Application of Neural Networks to Business Forecasting
3. Hands-on exercises in Neural Networks forecasting
4. Tips & Tricks for Improving Neural Networks based forecasts
5. Questions & Answers and Discussion
Motivation & Implementation of Neural Networks

- From biological neural networks ... to artificial neural networks

Mathematics as abstract representations of reality
> use in software simulators, hardware, engineering etc.

Information Processing in Nodes (Neurons)

- Modelling of biological functions in Neurons
  - 10-100 Billion Neurons with 10000 connections in Brain
  - Input (sensory), Processing (internal) & Output (motoric) Neurons

- CONCEPT of Information Processing in Neurons
  - Input Function (Summation of previous signals)
  - Activation Function (nonlinear)
    - binary step function \( \{0;1\} \)
    - sigmoid function: logistic, hyperbolic tangent etc.
  - Output Function (linear / Identity, SoftMax ...)

\[
\text{net}_i = \sum w_{ij} a_j - \theta_i, \quad a_i = f(\text{net}_i), \quad a_i = a_i \\
\]

\[
\alpha_i = \tanh \left( \sum w_{ij} a_j - \theta_i \right) \quad \text{with tanh:}
\]

\[
\tanh(x) = \frac{e^x - e^{-x}}{e^x + e^{-x}}
\]
Information Processing: Node Threshold logic

Node Function ➔ THRESHOLD LOGIC
1. weight individual input by connection strength
2. sum weighted inputs
3. add bias term
4. calculate output of node through transfer function [BINARY of SIGMOID]

*RERUN with next input pattern...

Architecture of Multilayer Perceptrons

- Architecture of a Multilayer Perceptron
  - Classic form of feed forward neural network!
  - Neurons \(u_n\) (units / nodes) ordered in Layers
  - Unidirectional connections with trainable weights \(w_{n,n}\)
  - Vector of input signals \(x_i\) (input)
  - Vector of output signals \(o_j\) (output)

\[ o_k = \tanh\left( \sum_i w_{ij} \tanh\left( \sum_i w_{ij} o_j - \theta_j \right) - \theta_k \right) \Rightarrow \text{Min!} \]
Agenda

Business Forecasting with Artificial Neural Networks

1. Introduction to Neural Networks
   a. Definition
   b. Preview Simulation of Neural Network Forecasting
   c. Neural Networks role in CORPORATE BUSINESS forecasting
   d. Motivation & brief history of Neural Networks
   e. From biological to artificial Neural Network Structures
   f. Network Training
2. Application of Neural Networks to Business Forecasting
3. Hands-on exercises in Neural Networks forecasting
4. Tips & Tricks for Improving Neural Networks based forecasts
5. Questions & Answers and Discussion

Neural Network Training with Back-Propagation

Training \rightarrow \text{LEARNING FROM EXAMPLES}
1. Initialize connections with randomized weights (symmetry breaking)
2. Show first Input-Pattern (independent Variables) (demo only for 1 node!)
3. Forward-Propagation of input values unto output layer
4. Calculate error between NN output & actual value (using error / objective function)
5. Backward-Propagation of errors for each weight unto input layer
   \begin{itemize}
   \item RERUN with next input pattern
   \end{itemize}
Neural Network Training = Error Minimization

- Minimize Error through changing ONE weight $w_j$

Error Backpropagation = 3D+ Gradient Decent

- Local search on multi-dimensional error surface
  - task of finding the deepest valley in mountains
    - local search
    - stepsize fixed
    - follow steepest decent
  - local optimum = any valley
  - global optimum = deepest valley with lowest error
  - varies with error surface
Dictionary for Neural Network Terminology

- Due to its neuro-biological origins, NN use specific terminology

<table>
<thead>
<tr>
<th>Neural Networks</th>
<th>Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Nodes</td>
<td>Independent / lagged Variables</td>
</tr>
<tr>
<td>Output Node(s)</td>
<td>Dependent variable(s)</td>
</tr>
<tr>
<td>Training</td>
<td>Parameterization</td>
</tr>
<tr>
<td>Weights</td>
<td>Parameters</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

→ don't be confused: ASK!

Agenda

Business Forecasting with Artificial Neural Networks

1. Introduction to Neural Networks
2. Application of Neural Networks to Business Forecasting
   a. Neural Networks for Time Series Prediction
   b. Neural Networks for Intervention / Event Time Series Prediction
   c. Neural Networks for Multiple Nonlinear Regression
   d. Comparison of NN to other Forecasting Methods
3. Hands-on exercises in Neural Networks forecasting
4. Tips & Tricks for Improving Neural Networks based forecasts
5. Questions & Answers and Discussion
**Time Series Prediction with Artificial Neural Networks**

- **ANN are universal approximators** ([Hornik/Stinchcomb/White92 etc.])
  - Forecasts as application of (nonlinear) function-approximation
  - various architectures for prediction (time-series, causal, combined...)

\[ \hat{y}_{t+h} = f(x_t) + \epsilon_{t+h} \]

- train multilayer perceptrons
  - model "best" architecture
  - many heuristics!
  - present data & train
  - minimize objective function

\[ \hat{y}_{t+1} = f(y_t, y_{t-1}, y_{t-2}, ..., y_{t-n-1}) \]

Non-linear autoregressive AR(p)-model

**Neural Network Training on Time Series**

- Sliding Window Approach of presenting Data

<table>
<thead>
<tr>
<th>Input</th>
<th>Present new data pattern to Neural Network</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calculate</td>
<td>Neural Network Output from Input values</td>
</tr>
<tr>
<td>Compare</td>
<td>Neural Network Forecast against (&lt; &gt;) actual value</td>
</tr>
<tr>
<td>Backpropagation</td>
<td>Change weights to reduce output forecast error</td>
</tr>
<tr>
<td>New Data Input</td>
<td>Slide window forward to show next pattern</td>
</tr>
</tbody>
</table>
Neural Network Architectures for Forecasting -
Single Nonlinear Autoregression

- Interpretation
  - Autoregressive modeling AR(p)-
  approach WITHOUT
  the moving average
  terms of errors
  ≠ nonlinear ARIMA
  - Similar problems / shortcomings as
    standard AR-models!
- Extensions
  - multiple output nodes
    = simultaneous auto-
    regressive models

\[ \hat{y}_{t+1} = \tanh \left( \sum_{i} w_{ij} \tanh \left( \sum_{k} w_{ki} y_{t-k} - \theta_{j} \right) - \theta_{i} \right) \]

Single nonlinear autoregressive AR(p)-model

Time Series Prediction with Artificial Neural Networks

- Which time series patterns can ANNs learn & extrapolate?
  [Pegels69/Gardner85]

- Simulation of
  Neural Network prediction of
  Artificial Time Series
Time Series Demonstration – Artificial Time Series

- Simulation of NN in Business Forecasting with NeuroPredictor

- Experiment: Prediction of Artificial Time Series (gaussian noise)
  - Stationary Time Series
  - Seasonal Time Series
  - Linear Trend Time Series
  - Trend with additive Seasonality Time Series

Time Series Prediction with Artificial Neural Networks

- Which time series patterns can ANNs learn & extrapolate? [Pegels69/Gardner85]

<table>
<thead>
<tr>
<th>No Trend Effect</th>
<th>Additive Trend Effect</th>
<th>Multiplicative Trend Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="No Trend Effect" /></td>
<td><img src="image2" alt="Additive Trend Effect" /></td>
<td><img src="image3" alt="Multiplicative Trend Effect" /></td>
</tr>
<tr>
<td><img src="image1" alt="No Trend Effect" /></td>
<td><img src="image2" alt="Additive Trend Effect" /></td>
<td><img src="image3" alt="Multiplicative Trend Effect" /></td>
</tr>
<tr>
<td><img src="image1" alt="No Trend Effect" /></td>
<td><img src="image2" alt="Additive Trend Effect" /></td>
<td><img src="image3" alt="Multiplicative Trend Effect" /></td>
</tr>
</tbody>
</table>

→ Neural Networks can forecast ALL major time series patterns
  - NO time series dependent preprocessing / integration necessary
  - NO time series dependent MODEL SELECTION required!!!
  - SINGLE MODEL APPROACH FEASIBLE!
Neural Network Architectures for Forecasting -
Single Nonlinear Autoregression – Multiple Step Ahead

\[ \hat{y}_{t+1}, \hat{y}_{t+2}, \ldots, \hat{y}_{t+n} = f (y_t, y_{t-1}, y_{t-2}, \ldots, y_{t-n}) \]

Single nonlinear autoregressive AR(p)-model

\[ y_t = \theta_1 + \theta_2 y_{t-1} + \theta_3 y_{t-2} + \ldots + \theta_p y_{t-p} + \varepsilon_t \]

Interpretation
- As single Autoregressive modeling AR(p)

Agenda

Business Forecasting with Artificial Neural Networks

1. Introduction to Neural Networks
2. Application of Neural Networks to Business Forecasting
   a. Neural Networks for Time Series Prediction
   b. Neural Networks for Intervention / Event Time Series Prediction
   c. Neural Networks for Multiple Nonlinear Regression
   d. Comparison of NN to other Forecasting Methods
3. Hands-on exercises in Neural Networks forecasting
4. Tips & Tricks for Improving Neural Networks based forecasts
5. Questions & Answers and Discussion
Neural Network Architectures for Forecasting - Nonlinear Autoregression Intervention Model

Interpretation
- As single Autoregressive modeling AR(p)
- Additional Event term to explain external events

Extensions
- multiple output nodes = simultaneous multiple regression

\[ \hat{y}_{t+1}, \hat{y}_{t+2}, \ldots, \hat{y}_{t+n} = f(y_t, y_{t-1}, y_{t-2}, \ldots, y_{t-n+1}) \]

Single nonlinear autoregressive AR(p)-model

Agenda

Business Forecasting with Artificial Neural Networks

1. Introduction to Neural Networks
2. Application of Neural Networks to Business Forecasting
   a. Neural Networks for Time Series Prediction
   b. Neural Networks for Intervention / Event Time Series Prediction
   c. Neural Networks for Multiple Nonlinear Regression
   d. Comparison of NN to other Forecasting Methods
3. Hands-on exercises in Neural Networks forecasting
4. Tips & Tricks for Improving Neural Networks based forecasts
5. Questions & Answers and Discussion
Neural Network Architectures for Forecasting -
Multiple nonlinear Multiple Regression

\[ \hat{y} = f \left( x_1, x_2, \ldots, x_n \right) \]
\[ \hat{y} = x_1 w_{1j} + x_2 w_{2j} + x_3 w_{3j} + \ldots + x_n w_{nj} - \theta_j \]
Nonlinear Regression Model

→ Interpretation
- Similar to linear Multiple Regression Modeling

Agenda

1. Introduction to Neural Networks
2. Application of Neural Networks to Business Forecasting
   a. Neural Networks for Time Series Prediction
   b. Neural Networks for Intervention / Event Time Series Prediction
   c. Neural Networks for Multiple Nonlinear Regression
   d. Comparison of NN to other Forecasting Methods
3. Hands-on exercises in Neural Networks forecasting
4. Tips & Tricks for Improving Neural Networks based forecasts
5. Questions & Answers and Discussion
Neural Network Architectures for Forecasting - Linear Autoregression

**Interpretation**
- weights represent autoregressive terms
- Same problems / shortcomings as standard AR-models!

**Extensions**
- multiple output nodes = simultaneous autocorrelation models
- Non-linearity through different activation function in output node

\[
\hat{y}_{t+1} = f(y_t, y_{t-1}, y_{t-2},\ldots,y_{t-n+1})
\]

\[
\hat{y}_{t+1} = y_t w_y + y_{t-1} w_{t-1} + y_{t-2} w_{t-2} + \ldots + y_{t-n+1} w_{t-n+1} - \theta
\]

linear autoregressive AR(p)-model

Neural Network Architectures for Forecasting - Nonlinear Autoregression (similar to Logistic Regression)

**Extensions**
- additional layers with nonlinear nodes
- linear activation function in output layer

\[
\hat{y}_{t+1} = f(y_t, y_{t-1}, y_{t-2},\ldots,y_{t-n+1})
\]

\[
\hat{y}_{t+1} = \tanh \left( \sum y_t w_t - \theta \right)
\]

non-linear autoregressive AR(p)-model
Neural Network Architectures for Forecasting -
Linear Multiple Regression

\[ \hat{y} = f(x_1, x_2, x_3, ..., x_n) \]
\[ \hat{y} = x_1w_{ij} + x_2w_{2j} + x_3w_{3j} + ... + x_nw_{nj} - \theta_j \]
Linear Regression Model

Neural Network Architectures for Forecasting -
Non-Linear Multiple Regression

\[ \hat{y}_{t+1} = f(y_t, y_{t-1}, y_{t-2}, ..., y_{t-n-1}) \]
\[ \hat{y}_{t+1} = \log \left( \sum_{i=1}^{n} y_{t}w_{ij} - \theta_i \right) \]
Nonlinear Multiple (Logistic) Regression Model
Modelling Flexibility in Neural Networks

- Flexibility on Input Variables → flexible coding
  - binary scale [0;1]; [-1,1]
  - nominal / ordinal scale (0,1,2,...,10 → binary coded [0001,0010,...])
  - metric scale (0.235; ...)
- Flexibility on Output Variables
  - binary → prediction of single class membership
  - nominal / ordinal → prediction of multiple class memberships
  - metric → regression (point predictions) OR probability of class membership!
- Number of Input Variables
  - ...
- Number of Output Variables
  - ...

→ One SINGLE network architecture → MANY applications

Classification of Neural Networks as Method

- Forecasting Method
  - Objective Forecasting Methods
    - Time Series Methods
      - Averages
      - Moving Averages
      - Naive Methods
      - Exponential Smoothing
      - Simple Regression
      - Multiple Regression
      - Neural Networks
    - Causal Methods
      - Simple ES
      - Linear ES
      - Seasonal ES
      - Damped Trend ES
  - Subjective Forecasting Methods
    - "Phrophecy" educated guessing...
      - Sales Force Composite
      - Analogy
      - Delphi
      - PERT
      - Survey techniques

Neural Networks ARE

- time series methods
- causal methods
& CAN be used as
- Averages & ES
- Regression...
Agenda

Business Forecasting with Artificial Neural Networks

1. Introduction to Neural Networks
2. Application of Neural Networks to Business Forecasting
3. Hands-on exercises in Neural Networks forecasting
   a. Experiment A: Time Series Forecasts
   b. Experiment B: Time Series Intervention Modelling
4. Tips & Tricks for Improving Neural Networks based forecasts
5. Questions & Answers and Discussion

Time Series Demonstration A - Lynx Trappings

- Simulation of NN in Business Forecasting with NeuroPredictor

- Experiment: Lynx Trappings at the McKenzie River
  - 3 layered NN: (12-8-1) 12 Input units - 8 hidden units – 1 output unit
  - Different lag structures: t, t-1, ..., t-11 (past 12 observations)
  - t+1 forecast → single step ahead forecast

- Benchmark Time Series
  [Andrews / Hertzberg]
  - 114 observations
  - Periodicity? 8 years?
Time Series Demonstration B – Event Model

- Simulation of NN in Business Forecasting with NeuroPredictor

- Experiment: Mouthwash Sales
  - 3 layered NN: (12-8-1) 12 Input units - 8 hidden units – 1 output unit
  - 12 input lags t, t-1, ..., t-11 (past 12 observations) → time series prediction
  - t+1 forecast → single step ahead forecast

  → Spurious Autocorrelations from Marketing Events
     - Advertisement with small Lift
     - Price-reductions with high Lift

Agenda

- Business Forecasting with Artificial Neural Networks

1. Introduction to Neural Networks
2. Application of Neural Networks to Business Forecasting
3. Hands-on exercises in Neural Networks forecasting
4. Tips & Tricks for Improving Neural Networks based forecasts
   a. Tips & Tricks in Data Pre-processing
   b. Tips & Tricks in Architecture Selection
   c. Tips & Tricks in Network Training & Selection
   d. Further Information on Neural Networks
5. Questions & Answers and Discussion
Decisions in Neural Network Modelling

- Data Pre-processing
  - Scaling
    - Normalizing to [0;1] or [-1;1]
- Modelling of NN architecture
  - Number of INPUT nodes
  - Number of HIDDEN nodes
  - Number of HIDDEN LAYERS
  - Number of OUTPUT nodes
  - Information processing in Nodes (Act. Functions)
  - Interconnection of Nodes
- Training
  - Initializing of weights (how often?)
  - Training method (backprop, higher order ...)
  - Training parameters
  - Evaluation of best model (early stopping)
- Application of Neural Network Model
- Evaluation
  - Evaluation criteria & selected dataset

Tip & Tricks in Data Pre-Processing

- Do’s and Don’ts
  - Outlier correction? YES!
  - De-Seasonalisation? NO!
  - De-Trending / Integration? NO / depends / preprocessing!
  - Normalisation? Not necessarily \(\rightarrow\) correct outliers!
  - Scaling Intervals \([0;1]\) or \([-1;1]\)? Both OK!
  - Apply headroom in Scaling? YES!
  - Interaction between scaling & preprocessing? limited
  - ...

\(\rightarrow\) Simulation Experiments
Outlier correction in Neural Network Forecasts?

- Neural networks are often characterized as
  - Fault tolerant and robust
  - Showing graceful degradation regarding errors
  - Fault tolerance = outlier resistance in time series prediction?

Tip & Tricks in Architecture Modelling

- Do’s and Don’ts
  - Number of input nodes? DEPENDS! \( \rightarrow \) use linear AC/PAC to start!
  - Number of hidden nodes? DEPENDS! \( \rightarrow \) evaluate each time (few)
  - Number of output nodes? DEPENDS on application!
  - fully or sparsely connected networks? ???
  - shortcut connections? ???
  - activation functions \( \rightarrow \) logistic or hyperbolic tangent? TanH !!!
  - activation function in the output layer? TanH or Identity!
  - ...
**Tip & Tricks in Network Training & Selection**

- Do’s and Don’ts
  - Selection of Model with lowest Validation error? NOT VALID!
  - Model & forecasting competition? Always multiple origin etc.!
  - ...
  - Selection of Training Algorithm? Backprop OK, DBD OK ...
  - Parameterisation of Training Algorithm? DEPENDS on dataset!
  - Use of early stopping? YES – careful with stopping criteria!
  - ...

> Simulation Experiments

---

**Agenda**

**Business Forecasting with Artificial Neural Networks**

1. Introduction to Neural Networks
2. Application of Neural Networks to Business Forecasting
3. Hands-on exercises in Neural Networks forecasting
4. Tips & Tricks for Improving Neural Networks based forecasts
   - a. Tips & Tricks in Data Pre-processing
   - b. Tips & Tricks in Architecture Selection
   - c. Tips & Tricks in Network Training & Selection
   - d. Further Information on Neural Networks
5. Questions & Answers and Discussion
**Software Simulators for Neural Networks**

**Commercial Software by Price**
- **High End**
  - Neural Works Professional
  - SPSS Clementine
  - SAS Enterprise Miner
- **Midprice**
  - Alyuda NeuroSolutions
  - NeuroShell Predictor
  - NeuroSolutions
  - NeuralPower
  - PredictorPro
- **Research**
  - Mathlab Library
  - R-package
  - NeuroLab
- **...**

**Public Domain Software**
- **Research oriented**
  - SNNS
  - JNNS JavaSNNS
  - JOONE
  - **...**

**FREE CD-ROM for evaluation**
- Data from Experiments
  - M3-competition
  - airline-data
  - lynx-data
  - beer-data
- **Software Simulators**

> Consider Tashman/Hoover Tables on forecasting Software for more details

---

**Neural Networks Software - Times Series friendly!**

- **Alyuda Inc.**
- **Ward Systems**
  - AITrilogy: NeuroShell Predictor, NeuroShell Classifier, GeneHunter
  - NeuroShell 2, NeuroShell Trader, Pro, DayTrader
- **Attrasoft Inc.**
  - Predictor
  - Predictor PRO
- **Promised Land**
  - Braincell
- **Neural Planner Inc.**
  - Easy NN
  - Easy NN Plus
- **NeuroDimension**
  - NeuroSolutions Cosnsultant
  - Neurosolutions for Excel
  - NeuroSolutions for Mathlab Trading Solutions
### Neural networks Software – General Applications

<table>
<thead>
<tr>
<th>Neuralware Inc</th>
<th>Neural Works Professional II Plus</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPSS</td>
<td>SPSS Clementine DataMining Suite</td>
</tr>
<tr>
<td>SAS</td>
<td>SAS Enterprise Miner</td>
</tr>
</tbody>
</table>

---

### Further Information

- **Literature & websites**
  - NN Forecasting website [www.neural-forecasting.com](http://www.neural-forecasting.com) or [www.bis-lab.com](http://www.bis-lab.com)
  - BUY A BOOK!!! Only one? Get: Reeds & Marks ‘Neural Smithing’

- **Journals**
  - Forecasting ... rather than technical Neural Networks literature!
    - JBF – Journal of Business Forecasting
    - IJF – International Journal of Forecasting
    - JoF – Journal of Forecasting

- **Contact to Practitioners & Researchers**
  - Associations
    - IEEE NNS – IEEE Neural Network Society
    - INNS & ENNS – International & European Neural Network Society
  - Conferences
    - Neural Nets: IJCNN, ICANN & ICONIP by associations (search google ...)
    - Forecasting: IJBF & IJSF conferences!
  - Newsgroups news.comp.ai.neural
  - Call Experts you know ... me ;-)
Agenda

Business Forecasting with Artificial Neural Networks

1. Introduction to Neural Networks
2. Application of Neural Networks to Business Forecasting
3. Hands-on exercises in Neural Networks forecasting
4. Tips & Tricks for Improving Neural Networks based forecasts
   a. Questions & Answers and Discussion
      a. Advantages & Disadvantages of Neural Networks
      b. Discussion

Advantages ... versus Disadvantages!

**Advantages**
- ANN can forecast any time series pattern \((t+1)\)
  - without preprocessing
  - no model selection needed!
- ANN offer many degrees of freedom in modeling
  - Freedom in forecasting with one single model
  - Complete Model Repository
    - linear models
    - nonlinear models
    - Autoregression models
    - single & multiple regres.
    - Multiple step ahead
    - ...
Questions, Answers & Comments?

Summary
- ANN can forecast any time series pattern (t+1)
  - without preprocessing
  - no model selection needed!
- ANN offer many degrees of freedom in modeling
  - Experience essential!
  - Research not consistent

What we can offer you:
- NN research projects with complimentary support!
- Support through MBA master thesis in mutual projects

Sven F. Crone
crone@bis-lab.de
SLIDES & PAPERS available:
www.bis-lab.de
www.lums.lancs.ac.uk

Contact Information

Sven F. Crone
Research Associate
Lancaster University Management School
Department of Management Science, Room C54
Lancaster LA1 4YX
United Kingdom

Tel +44 (0)1524 593867
Tel +44 (0)1524 593982 direct
Tel +44 (0)7840 068119 mobile
Fax +44 (0)1524 844885

Internet www.lums.lancs.ac.uk
eMail s.crone@lancaster.ac.uk