



Machine Learning in Steel Industry

Machine Learning for Complex Processes

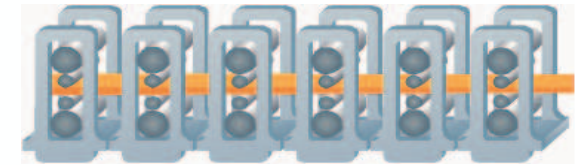
You might be driving in neuro-steel

Volker Tresp and Bernhard Lang

Siemens AG



Use of Neural Modules for Adaptation Along a Hot Strip Mill in Year 2000



■ Short stroke control

■ Rolling force

■ Natural width spread

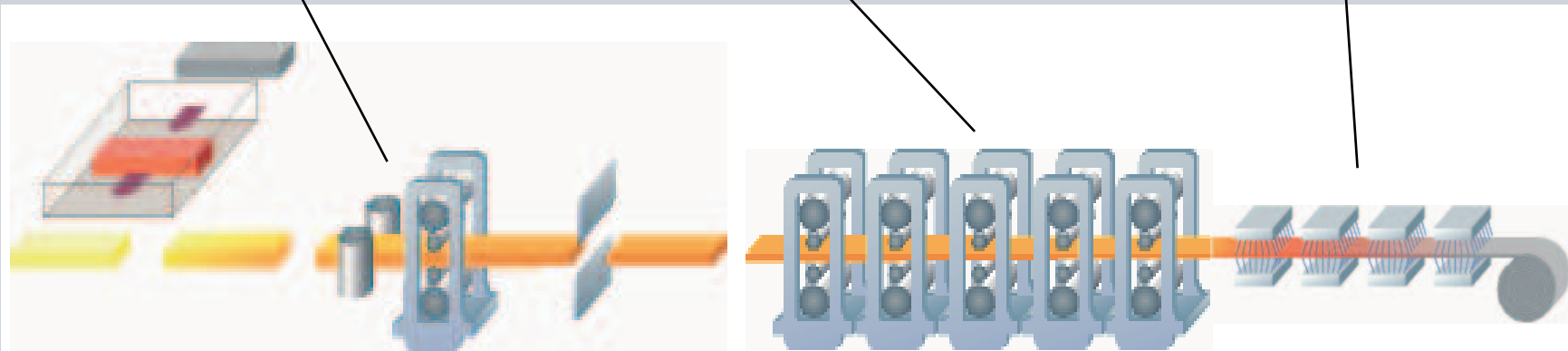
■ Strip temperature

■ (Profile, flatness)

■ (Flow stress)

■ Heat transfer coefficients

■ Mechanical properties



furnace

roughing train

finishing train

cooling section

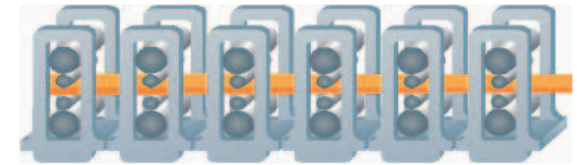
coil

Prediction of Rolling Force (start: 1990)



- What is the force required to obtain a certain reduction in thickness based on approximately a dozen features
- An analytical formula with table based adaptation was being used but with increasable prediction accuracy
- Goal: increase accuracy by neural network (instead of table)
- Online adaptation was essential ('daily form of the plant')

Open Questions at the Beginning of the Project



- Can we improve accuracy?
- Can we ensure stability?
 - The neural network might do strange things with its resources; over 2000 different kinds of steel must be processed
- How about extrapolation into the regions where no data points have been available?
- Can we use additional inputs (material components)?
- Model selection: how many hidden units?
- How can we implement safety features?
- What can we do for a new plant with no data available?
- How much service would be required?

Project Development



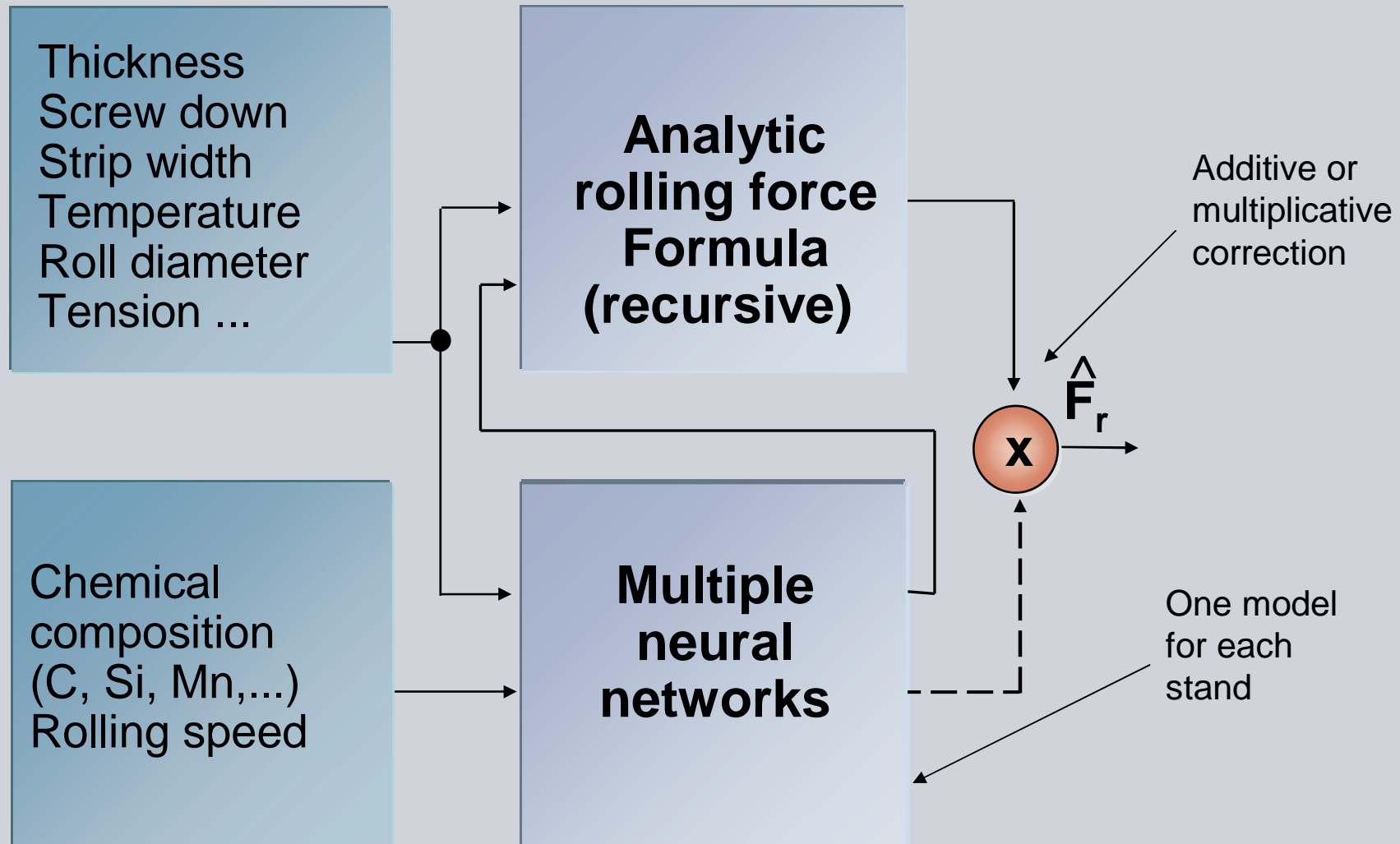
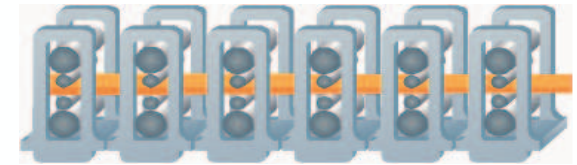
- Can we improve the table based adaptation?
 - Based on initial experiments it became quickly clear that the table based adaptation could be improved by a neural network
- How about extrapolation into the regions where no data have been available? Can we implement safety features?
 - We used the analytic formula as reference in various ways
 - Adding artificially generated data from the analytical formulas (NIPS*91)
 - Other Bayesian ways of incorporating prior knowledge
 - Learn additive or multiplicative correction for analytic formula
 - Bound the amount of correction of the neural network

Project Development

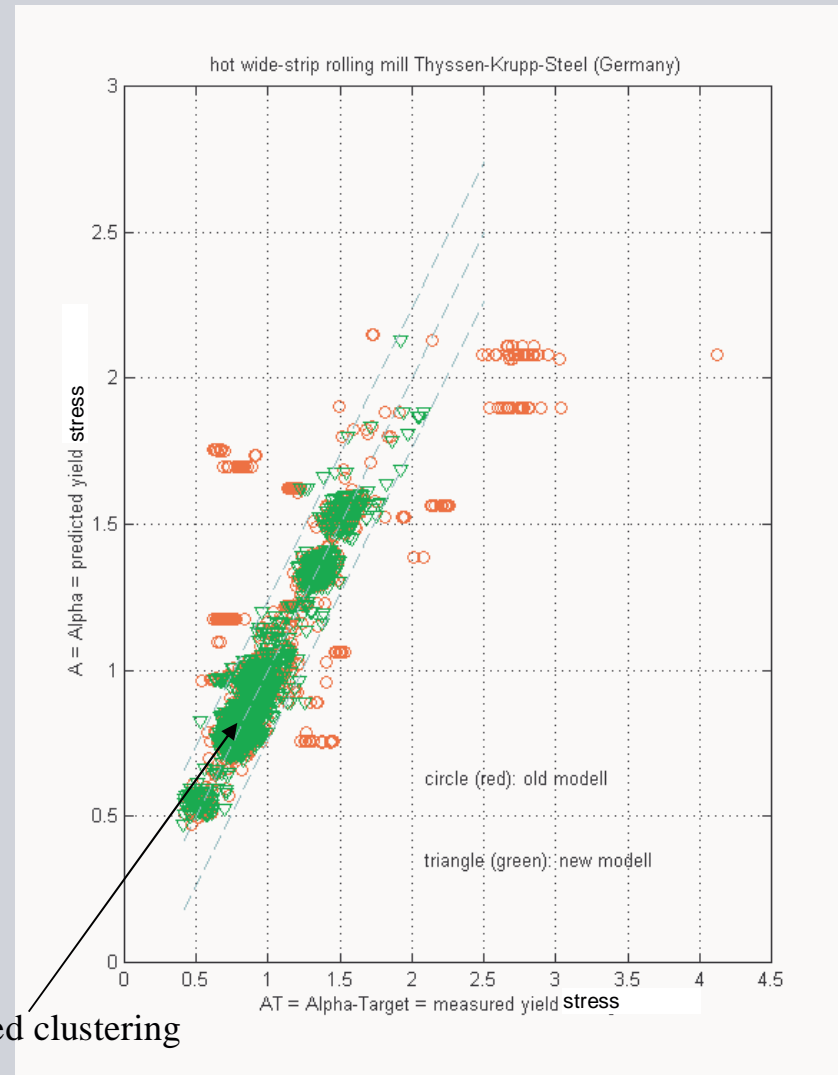
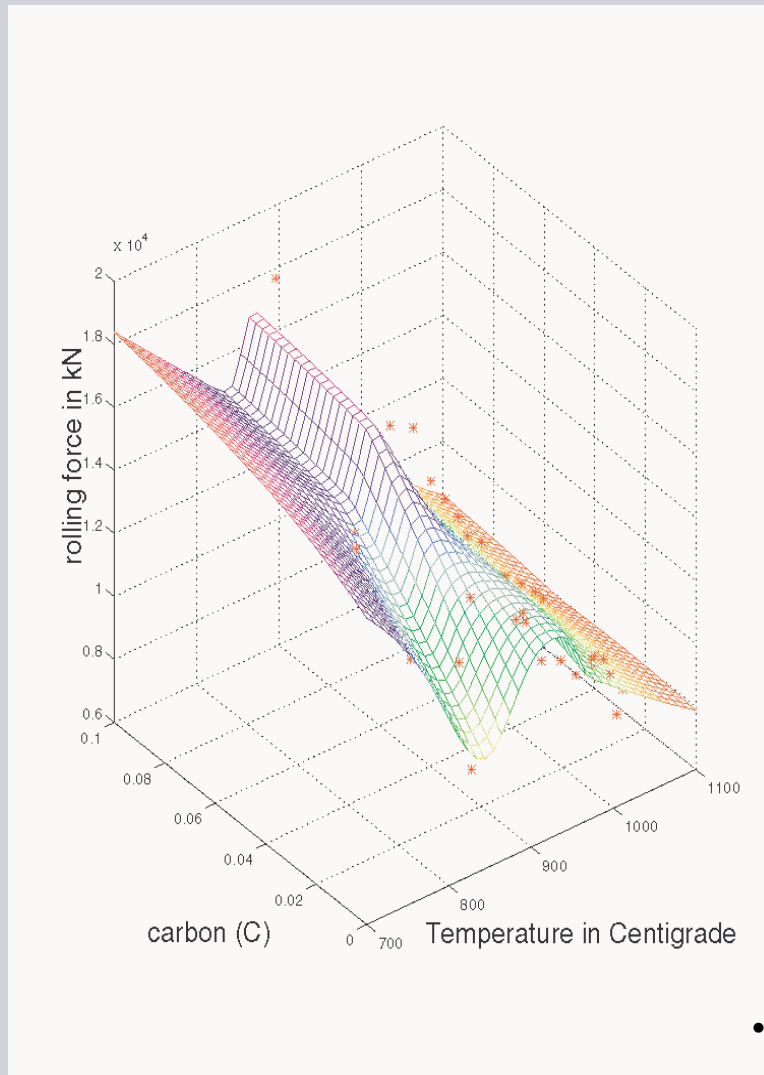
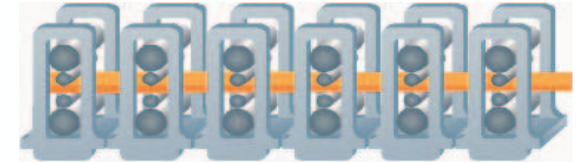


- Can we use additional inputs (material components)?
 - Material properties were not available but chemical composition could be supplied
 - For the neural network, the additional features are simply additional inputs

Combination of Analytical Model and Neural Network in Year 2000



Nonlinearities and Performance

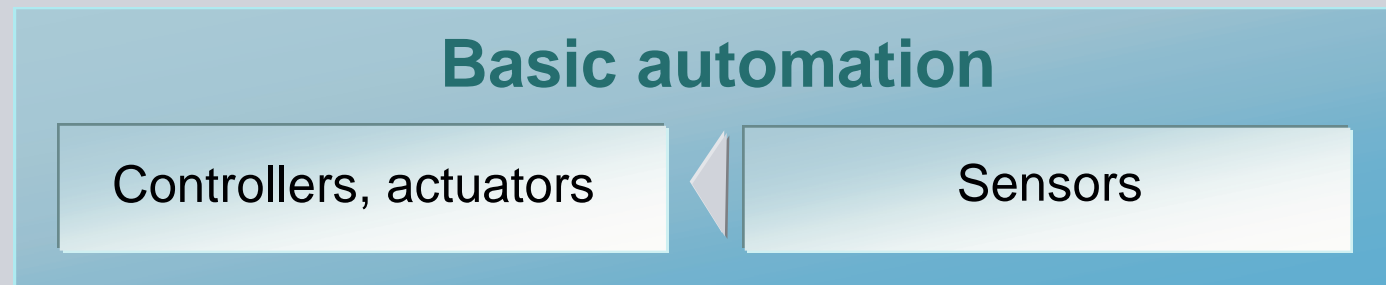
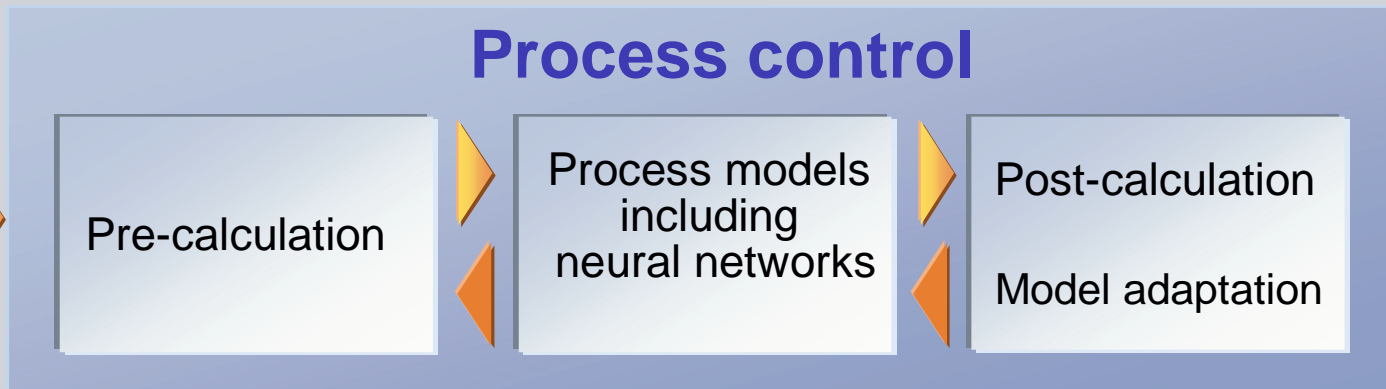


- Improved clustering
 - Transition to three Neural Networks
- © Siemens AG, Corporate Technology

Process Control System



Primary data
desired values



Project Development



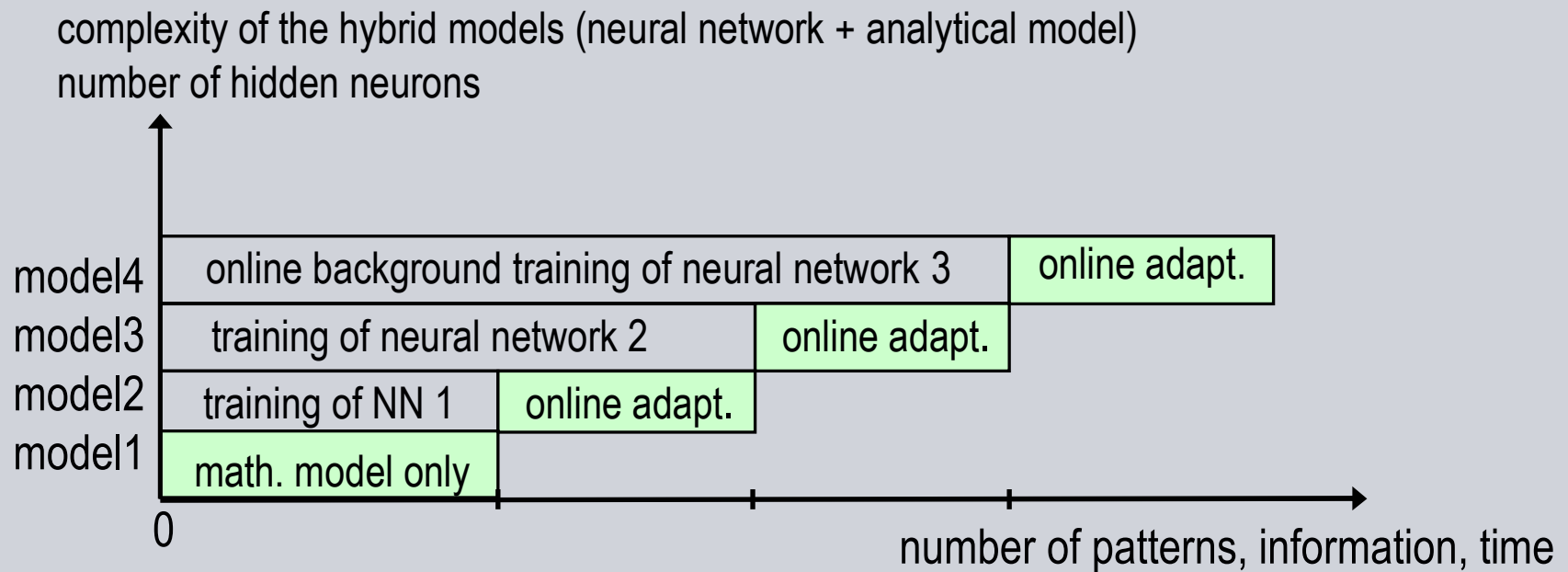
- Can we ensure stability? The neural network might do strange things with its resources (focus on only a small portion of input space?)
- What can we do for a new plant with no data available?
- Model selection: how many hidden units?
 - A specific mixture of resource optimization and online learning was used which lead to a stable adaptive system
 - The model increases in complexity if more data become available

Neural Network Initialization Learning: Basics

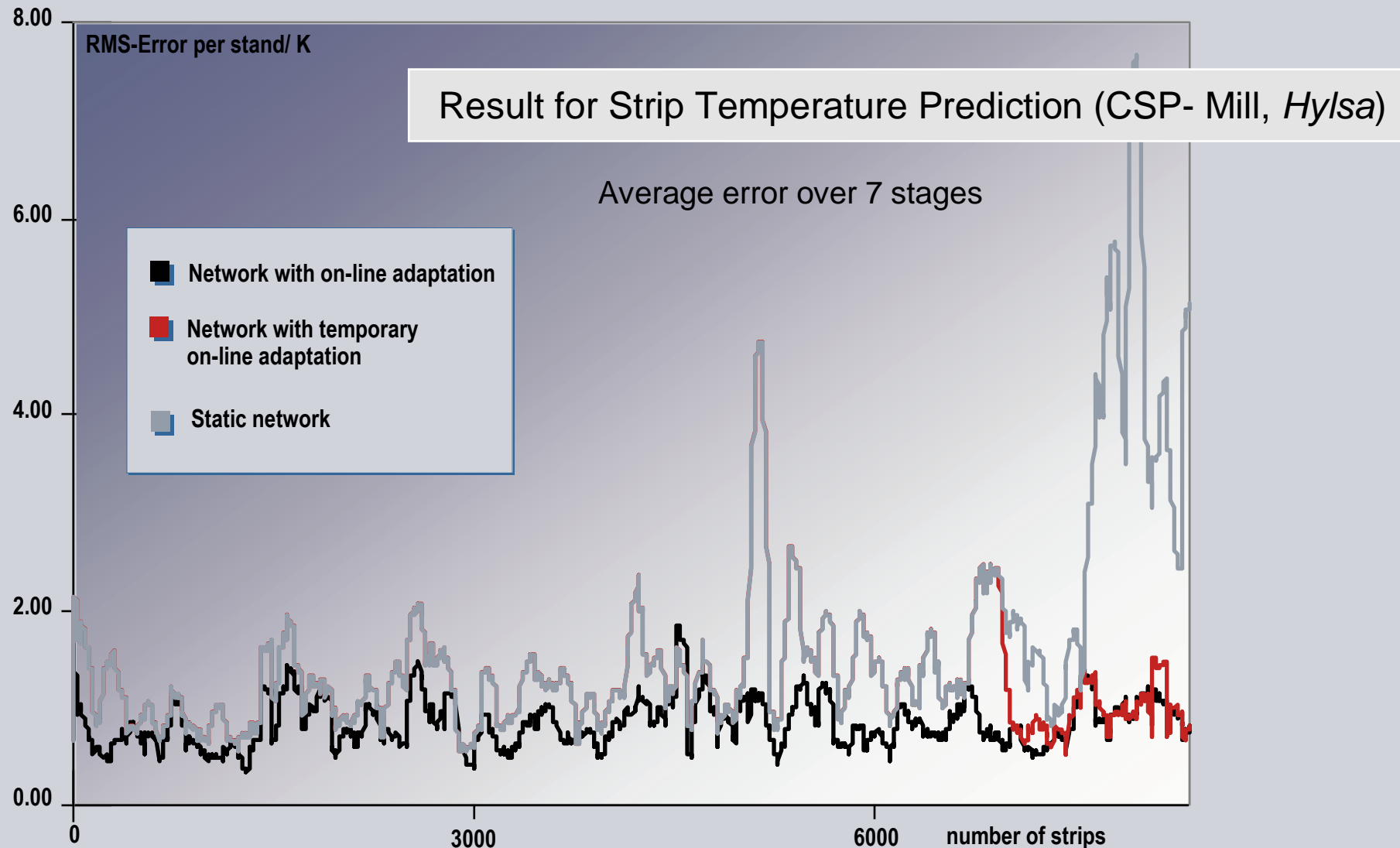


Online identification of the process by a **model switch approach**:

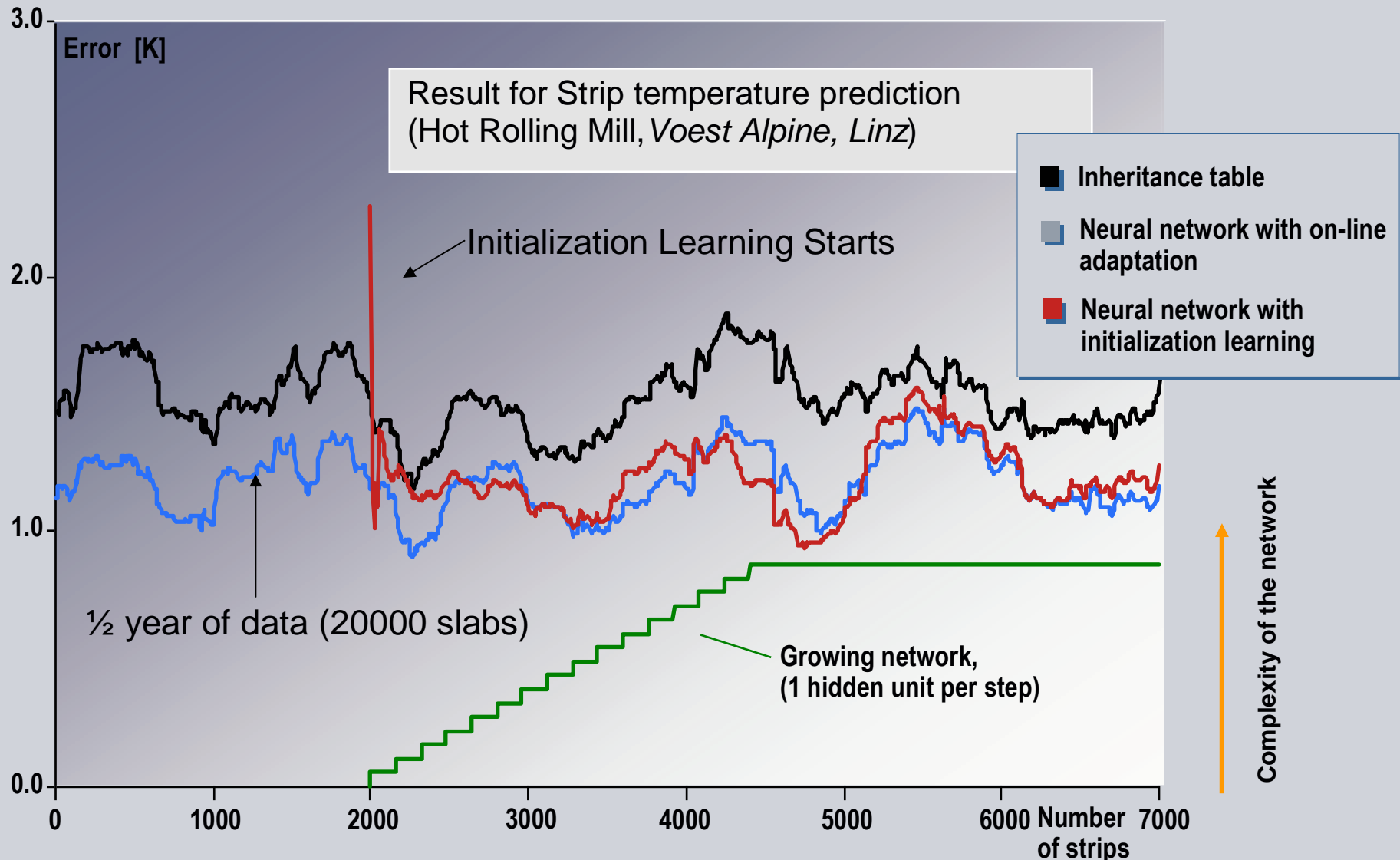
- The more data, the more global and complex the active model
- Adaptation of parameters and model structure



Stable On-Line Adaptation: Results



Neural Network Initialization Learning: Results



Project Development



MLP versus RBF?

- On a fixed data set, both approaches gave good performance
- The RBF model was more appropriate to deal with the online learning aspect: only the linear parameters are adapted online
- A modified Widrow-Hoff learning rule was used
- Dumb-man adaptation

How much service would be required?

- The system runs autonomously

Is rolling force prediction important: yes, for thickness performance and stable operation of the mill

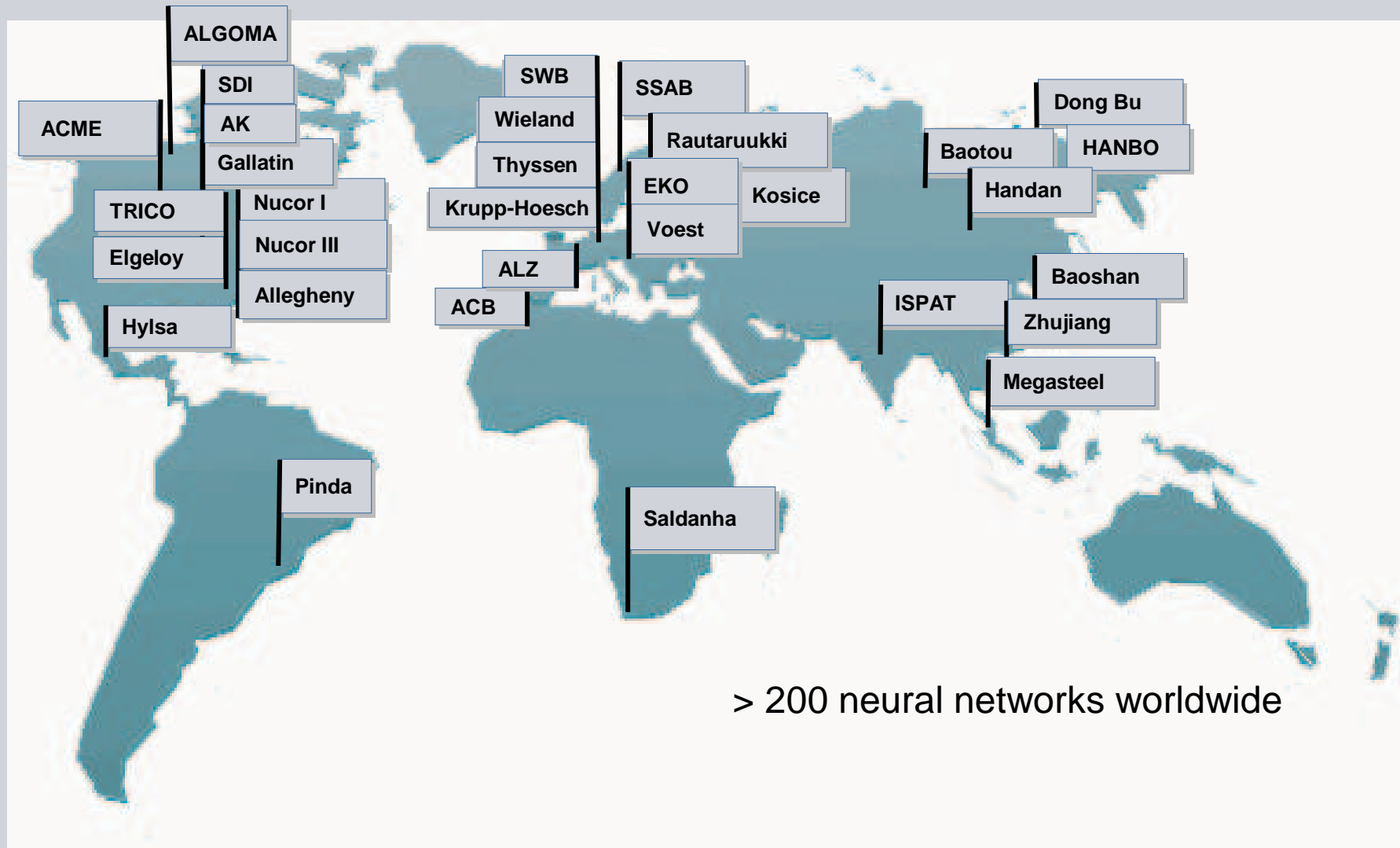
Tasks Involving Neural Networks in Steel Plants



Task	Plant type	Improvement (year 1993 → 1996)
Pre-calculation of rolling force, strip temperature, natural spread short stroke control heat transfer coeff. (cooling section)	Hot rolling mill	15-30%
	Hot rolling mill	25%
	Hot rolling mill	25%
	Hot rolling mill	
	Hot rolling mill	20%
Pre-calculation of rolling force, rolling torque and forward slip	Cold rolling mill	10-25%
	Cold rolling mill	
Material properties, (e.g. yield strength, tensile strength)	Hot rolling mill	new
Electrode control	Electric arc furnace	5%

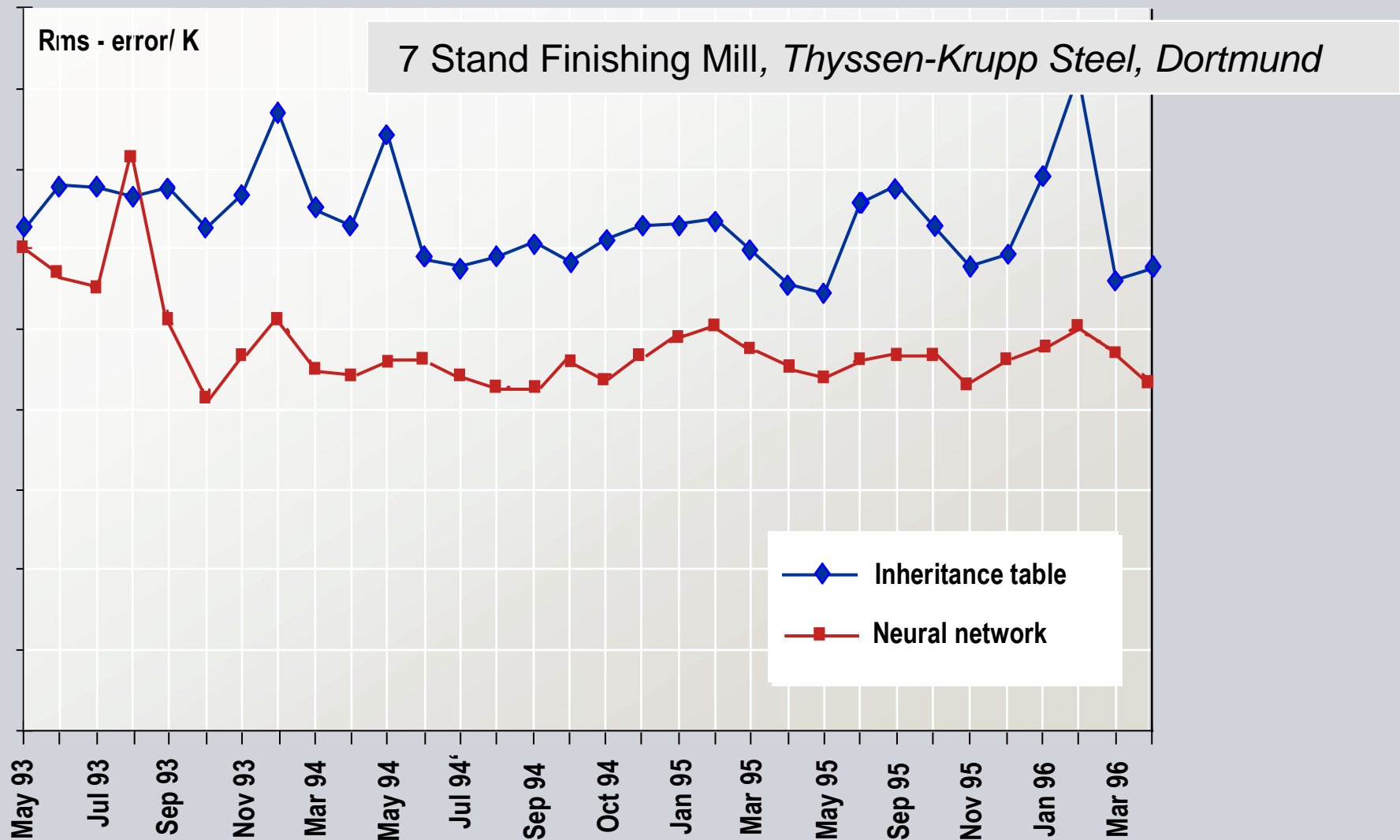
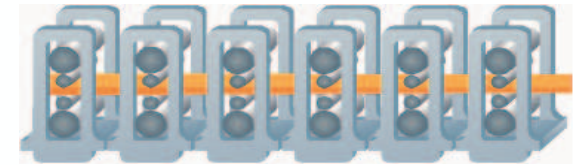


Examples for World-Wide Installations



> 200 neural networks worldwide

Prediction of Strip Temperature: consistent improvement over 3 years



Further Developments since Year 2000



- Physical models have been improved
- Further development of Neural Network Package SIANS (downward compatible, hence with possibility to upgrade existing applications)
- Neural Networks are employed for adaptation of physical parameters, hence they are transferable from plant to plant

→ Still improved

- precision,
- extensibility (to new steel grades) and
- stability

of neural network applications in steel industry