Maturing a network structure for rule extraction

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Aims and Scope. Neural networks are often used to adapt a generic control formulation to the process at hand. The formal model or expert rule base provides a formulation of the domain problem but a further tuning to the physical reality tends to be cumbersome, error-prone and difficult to maintain. As the process evolves in time, additional model adjustments are often required and the search for alternative techniques becomes even more pressing.
In a layered control hierarchy, the generic formulation can be shaped to provide a strategy that is subsequently detailed by a set of neural networks, each reflecting part of the physical reality. This decoupling of domain and process specific effects works reasonably well, but it remains hard to guarantee the integrity of the neural activations. For proper quality monitoring, it is required that the neural knowledge can be extracted isomorphic to the original generic formulation. To achieve this goal, a novel means has to be devised to optimally match sensitivity to robustness in neural classification & clustering.

Approach. The classical learning approach for neural networks is based on gradient optimization in the error space. Its operation can be explained from the Gravitational Field analogon as known from physics: by weight adaptation through the learning rule an example is moved along the energy field to the attracting cluster. However, between two clusters, there will be a point where the attraction is zero, which is the major cause for the indeterminism as often observed during recall.
Alternatively we study the learning operation by the Bipolar Particle analogon as known from microelectronics: the distribution of positive and negative examples is influenced by addition of structural redundancy to create a dead zone between clusters. This eliminates the occurrence of indeterminism and therefore allows optimizing classifier sensitivity and clustering robustness independently of one another.

Results. The new model explains the operational robustness seen in earlier experiments on finite number representation in neural hardware realizations, novelty detection and temporal prediction. The enhanced robustness is shown to be crucial for the purposeful extraction of knowledge from a trained neural network in a format isomorphic to the original domain specification. Natural fluctuations in the measured process values are smoothed away without statistical averaging, simultaneously eliminating the need for noise cleaning in the retrieval of the knowledge rules.
A robust neural structure is the corner stone of a neural decision support system for ill-defined processes. Though original aimed for control of industrial production, current development is in logistic processes and fleet management, where many low quality sensory data streams need to be combined for a high quality long-term prediction.

Additional Reading.
See section. Intelligent Signal Processing in "http://www.it.lth.se/users/lambert/publications.htm"

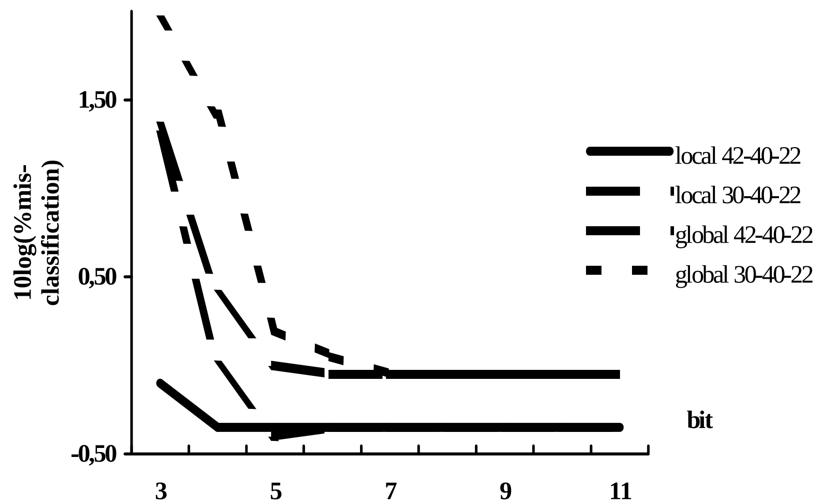

Fig. 1: Impact of redundancy on license-plate mis-classification.

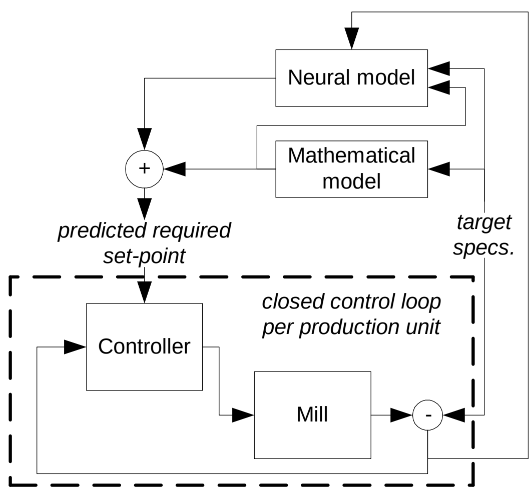

Fig. 2: Steel-mill control architecture