NIPS*95 Workshop Report - Neural Networks for Signal Processing

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1 Introduction

Nonlinear signal processing methods using neural network models form a topic of some recent interest. A common goal is for neural network models to outperform traditional linear and nonlinear models. Many researchers are interested in understanding, analysing and improving the performance of these nonlinear models by drawing from the well established base of linear systems theory and existing knowledge in other areas.

In the context of neural network models, a variety of methods have been proposed for capturing the time-dependence of signals. A common approach is to use recurrent connections or time-delays within the network structure. On the other hand, many signal processing techniques have been well developed over the last few decades. Recently, a strong interest has developed in understanding how better signal processing techniques can be developed by considering these different approaches.

A major aim of this workshop was to obtain a better understanding of how well this development is proceeding. For example, the different model structures raise questions such as "how suitable are the various neural networks for signal processing problems ?" and "what are the important issues which need to be considered in this field ?".

2 The presentations

The workshop was divided into two parts - the morning session had a focus on speech technology and the afternoon session had a focus on recurrent networks.

Herve Bourlard of Faculte Polytechnique de Mons and ICSI (*Hybrid use of hidden Markov models and neural networks for improving state-of-the-art speech recognition systems*), gave an insightful discussion on how neural network models and hidden Markov models may be combined in a speech recognition system. This also indicates other areas for research such as *hybrid* models (e.g. Fuzzy HMMs) and in applying HMMs to fields other than speech. A particular problem in large real-world systems such as speech recognizers, concerns the difficulties in testing new methods, due to the complex interaction between components of the recognizer and the large number of parameters to be trained.

John Hogden of Los Alamos National Laboratory (*A maximum likelihood approach to estimating speech articulator positions from speech acoustics*), presented some very recent results on an algorithm (MALCOM) for obtaining the positions of human speech articulators from measurements of the speech waveform. The algorithm is based on maximum likelihood estimation and provides better accuracy of the articulator position than continuity mapping techniques.

Shun-ichi Amari (co-authors **A.Cichocki** and **H. Yang**) of RIKEN (*Blind separation of signals - Information geometric point of view*), presented some very elegant results which provide a theoretical basis for blind source separation based on the concepts of Jutten-Herault. An efficient new on-line learning algorithm for blind separation of mixtured signals was presented. This algorithm is motivated by the Gram-Charlie expansion of density functions and information-geometric dynamics of the manifold of matrices.

Andrew Back of the University of Queensland (*Issues in signal processing relevant to dynamic neural networks*) gave an insight into how some methods from signal processing may be advantageously applied to dynamic neural networks. In particular, the problem of high sensitivity which is known to occur in linear systems, was demonstrated in recurrent networks. A method of overcoming the problem was presented, resulting in a new robust recurrent network architecture.

John Steele and **Aaron Gordon** of the Colorado School of Mines (*Hierarchies of recurrent neural networks for signal interpretation with applications*), presented work done using recurrent neural networks on a number of problems. These included radar signal identification, trajectory estimation, robot control, and online monitoring of epoxy cure processes. A constructive recurrent network model proposed showed significant performance improvements of previous constructive recurrent network algorithms. In particular, the problem of poor interpolation between data points was overcome using the new model. A further technique which was used successfully on complicated problems was to use hierarchies of recurrent networks.

Stephen Piche of Pavilion Technologies (*Discrete Event Recurrent Neural Networks*), presented some impressive results based on using neural networks in a variety of commercial applications. Importantly, it was noted that a high degree of knowledge of the process was essential to design an effective network, tailored to the problem. This is quite a different approach where it is often the case that a network class is specified with only the size of the network and weights to be learned, before applying it to a problem. In this case however, a neural network architecture was selected as part of a careful analysis of the problem.

3 Summary

The common themes running through all the talks were that

1. Beyond linear systems, there are many problems which are indeed nonlinear and most definitely require nonlinear models in order to produce acceptable (i.e. commercial useful) results.
2. The applications which were considered by presenters were *real world* problems under *non-ideal* conditions.

   It is important to consider what is meant by real-world. While not trying to provide an exhaustive definition, we consider real world problems to encompass what one

might consider as the "fundamental problem" for which one might consider a text-book solution and the miscellaneous technical difficulties which arise to due imperfections in the modelling process, measurements of the data, differences between the theoretical and actual performance of a system due differences in the theoretical design and the system actually implemented.

For example, the speech problem consists of a large database with the models having many parameters. The voice articulation problem is based on real data, not simulations. The blind source separation problem is concerned with the convergence of the model.

3. There was an emphasized need to consider the model carefully in relation to the physical constraints of the problem.
4. Many problems are *data poor*.

Areas for future work are indicated by the above points. There is a need to develop models which can cope better with the types of problems encountered in real-world situations. Neural networks have certainly demonstrated significant advantages over conventional "linear" approaches for a range of signal-processing problems. However, it is clear that there is a need for the models to be better able to cope with problems such as poor training data (noisy, sparse etc.), interaction between model components, accuracy and robustness of models, and system constraints. These are the same sorts of issues that followed the initial development of linear adaptive systems. The first results established the principles while subsequent work, taking much longer (and still continuing), focussed on these more difficult problems which are largely related to real-world issues.

Therefore we propose that in order for neural network based models to be of more value in practical applications, significant effort will need to be devoted to these types of issues listed above, paralleling the development of adaptive filters and linear systems theory. Much of this has already been commenced and we see this as important, on-going work. We look forward with anticipation to such developments.

Our thanks to all speakers and participants at the workshop, also to Michael Perrone and the NIPS Committee for providing the facilities and support necessary to ensure a productive workshop. Feedback for future workshops would be greatly appreciated. As much of the material presented was done either based on existing papers or was quite recent, requests for papers or notes from the workshop presentations should be directed to the individual authors.