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CONTRIBUTED ARTICLE

Predictive Modular Neural Networks for Time Series Classification

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Abstract—*A predictive modular neural network (PREMONN) architecture for time series classification is presented. The PREMONN has a hierarchical structure. The bottom level consists of a bank of linear or nonlinear predictor modules. The top level is a decision module which employs Bayesian or nonprobabilistic decision rules. For various choices of prediction and decision modules, convergence to correct classification is proven. Also it is shown that PREMONN is robust to noise and the speed/accuracy tradeoff is investigated. The analysis is mainly mathematical; however, we also present classification experiments to corroborate our conclusions. Copyright © 1996 Elsevier Science Ltd.*

Keywords—Modular neural networks, Hierarchical neural networks, Adaptive neural networks, Time series, Classification, Prediction, Bayesian decision rules.

1. INTRODUCTION

Let us consider the following time series classification problem. A time series y_t, $t = 1, 2, \ldots$,[1] is produced by a source $S(\theta_k)$, where θ_k is a parameter taking values in a finite set $\Theta = \{\theta_1, \ldots, \theta_K\}$. The source that produces the time series should be identified; in other words the "true" or "best" value of θ_k should be computed.

For example, the time series $y_1, y_2, \ldots$ may be a speech signal, and the parameter θ_k a phoneme label taking values in the set $\Theta = \{[ah], [oo], \ldots\}$. When the speech signal, for instance, corresponds to the phoneme [ah], $y_1, y_2, \ldots$ is produced by $S([ah])$. This type of problem arises in phoneme recognition (Waibel et al., 1989), radar (Haykin & Cong, 1991) and sonar (Gorman & Sejnowski, 1988) signal classification, processing of seismic signals (Lainiotis et al., 1988), EEG (Zetterberg et al., 1981) and ECG (Zhu et al., 1989) analysis, etc. A Bayesian approach to classification is quite common.

A significant trend of current connectionist research (for classification as well as other pro-

blems) is the development of training algorithms that partition the parameter space into regions, and fit a local model to each region. This approach is implicit in many earlier papers (Farmer & Sidorowich, 1988; Moody, 1989) but is recently being reexamined and formulated in the more suggestive language of *probability mixtures, local experts* (Nowlan, 1990b; Jacobs et al., 1991; Neal, 1991; Jordan & Jacobs, 1992), *committees* (Schwarze & Hertz, 1992a, b), *neural ensembles* (Perrone & Cooper, 1993), etc. More important than the change in vocabulary, is the development of new, adaptive methods for efficient combination of the local models, as in Ayestaran and Prager (1993), Baxt (1992), Beyer and Smieja (1993), Jacobs et al. (1991), Jordan and Jacobs (1992), Kadirkamanathan and Niranjan (1992), Schwarze and Hertz (1992a, b), etc. We find *Bayesian model combination* methods particularly interesting. Our work lies in this direction and has common elements with Jacobs et al. (1991), Jordan and Jacobs (1992), Neal (1991), Nowlan (1990a, b, c), Shadafan and Niranjan (1993).

Our first approach to time series classification is based on Bayesian combination of local predictors. This draws on the classical *partition algorithm* first used in the context of control theory (Hilborn & Lainiotis, 1969; Lainiotis, 1971). We have introduced its use to time series classification in a previous paper (Petridis & Kehagias, 1993). The space of time series

Requests for reprints should be sent to V. Petridis, Division of Electronics and Computer Engineering, Department of Electrical Engineering, Aristotle University of Thessaloniki, 540 06 Thessaloniki, Greece; e-mail: kehagias@egnatia.ee.auth.gr

[1] In what follows we use interchangeably the notations "y_t, $t = 1, 2, \ldots$" or "$y_1, y_2, \ldots$" or "$\{y_t\}_{t=1}^{\infty}$" to denote a time series.

Predictive Modular Neural Networks Applications To Time Series

JAN G. DE GOOIJER

Predictive Modular Neural Networks Applications To Time Series:

Predictive Modular Neural Networks Vassilios Petridis,Athanasios Kehagias,1998-09-30 The subject of this book is predictive modular neural networks and their ap plication to time series problems classification prediction and identification The intended audience is researchers and graduate students in the fields of neural networks computer science statistical pattern recognition statistics control theory and econometrics Biologists neurophysiologists and medical engineers may also find this book interesting In the last decade the neural networks community has shown intense interest in both modular methods and time series problems Similar interest has been expressed for many years in other fields as well most notably in statistics control theory econometrics etc There is a considerable overlap not always recognized of ideas and methods between these fields Modular neural networks come by many other names for instance multiple models local models and mixtures of experts The basic idea is to independently develop several subnetworks modules which may perform the same or re lated tasks and then use an appropriate method for combining the outputs of the subnetworks Some of the expected advantages of this approach when compared with the use of lumped or monolithic networks are superior performance reduced development time and greater flexibility For instance if a module is removed from the network and replaced by a new module which may perform the same task more efficiently it should not be necessary to retrain the aggregate network

Predictive Modular Neural Networks Vassilios Petridis,Athanasios Kehagias,2011-05-15   *Neuronale Netze zur Prognose und Disposition im Handel* Sven Crone,2010-03-26 Sven F Crone bietet eine fundierte Analyse der Grundlagen zur Prognose Disposition und der Verfahrensklasse der Neuronalen Netze und zeigt an Beispielen neue Wege zu ihrer Anwendung auf   **Recent Developments and the New Direction in Soft-Computing Foundations and Applications** Lotfi A. Zadeh,Ronald R. Yager,Shahnaz N. Shahbazova,Marek Z. Reformat,Vladik Kreinovich,2018-05-28 This book is an authoritative collection of contributions in the field of soft computing Based on selected works presented at the 6th World Conference on Soft Computing held on May 22 25 2016 in Berkeley USA it describes new theoretical advances as well as cutting edge methods and applications Theories cover a wealth of topics such as fuzzy logic cognitive modeling Bayesian and probabilistic methods multi criteria decision making utility theory approximate reasoning human centric computing and many others Applications concerns a number of fields such as internet and semantic web social networks and trust control and robotics computer vision medicine and bioinformatics as well as finance security and e Commerce among others Dedicated to the 50th Anniversary of Fuzzy Logic and to the 95th Birthday Anniversary of Lotfi A Zadeh the book not only offers a timely view on the field yet it also discusses thought provoking developments and challenges thus fostering new research directions in the diverse areas of soft computing   Hybrid Intelligent Systems Oscar Castillo,Patricia Melin,Witold Pedrycz,2007-07-23 This volume offers a general view of recent conceptual developments of Soft Computing SC It presents successful new applications of SC to real world problems leading to better performance than traditional methods The edited

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problems Soft Computing SC consists of several intelligent computing paradigms including fuzzy logic neural networks and bio inspired optimization algorithms which can be used to produce powerful hybrid intelligent systems The book is organized in five main parts which contain groups of papers around a similar subject The first part consists of papers with the main theme of hybrid intelligent systems for control and robotics which are basically state of the art papers that propose new models and concepts which can be the basis for achieving intelligent control and mobile robotics The second part contains papers with the main theme of hybrid intelligent systems for pattern recognition and time series prediction which are basically papers using nature inspired techniques like evolutionary algorithms fuzzy logic and neural networks for achieving efficient pattern recognition or time series prediction The third part contains papers with the theme of bio inspired and genetic optimization methods which basically consider the proposal of new methods and applications of bio inspired optimization to solve complex optimization of real problems The fourth part contains papers that deal with the application of intelligent optimization techniques in real world problems in scheduling planning and manufacturing The fifth part contains papers with the theme of evolutionary methods and intelligent computing which are papers considering soft computing methods for applications related to diverse areas such as natural language processing recommending systems and optimization   *INTERNATIONAL JOURNAL OF FORECASTING* JAN G. DE GOOIJER,2002   The 1994 IEEE International Conference on Neural Networks ,1994   *Applications and Science of Computational Intelligence* ,1999   Neural Networks Theory, Technology, and Applications Patrick K. Simpson,1996   IJCNN'99 IEEE Neural Networks Council,1999 IJCNN 99 spans the neural network field from neurons to consciousness training algorithms to robotics chaos to control fuzzy logic to evolutionary computing Starting with a symposium on biological neural networks it explores the potential impact of neurobiological discoveries   **Bayesian Inference and Maximum Entropy Methods in Science and Engineering** Kevin H. Knuth,2005-12-06 All papers were peer reviewed For over 25 years the MaxEnt workshops have explored Bayesian and Maximum Entropy methods in scientific engineering and signal processing applications This proceedings volume covers all aspects of probabilistic inference such as techniques applications and foundations Applications include physics space science earth science biology imaging graphical models and source separation   **Control Applications and Ergonomics in Agriculture 1998** N. Sigrimis,P.P. Groumpos,1999 In this workshop an attempt was made to fuse the disciplines involved in the requirements specification design and implementation of control systems for the automation of agricultural systems The need to meet the demanding specifications for increasingly complex agricultural systems is being addressed by using increasingly sophisticated models and control algorithms In parallel the ever decreasing profit margins in the agricultural sector no longer permit agriculture to operate in the traditional manner but are forcing it to transform into a contemporary business with all the complexities that this implies The work environment is changing rapidly and humans are moving to positions of supervision and management while automation and robotics are taking over many of the menial and tedious

tasks Modern technological developments in industrial management and control are entering agriculture and transforming it rapidly into an industry Smaller agricultural systems are being linked to produce hierarchical large scale agricultural systems whose management and control demands high level intelligent decision support mechanisms Local and wide area networks provide the relevant agricultural and economic data and facts to central production management systems where decisions are made and subsequently transferred to remote locations for execution Agriculture which is a highly distributed operation is taking advantage of modern communications networks unifying remote locations into a virtual world Agriculture has been making significant steps in producing food and fibers of improved quality in a highly constrained economic environment Robust control of such a largely uncertain system demands that application domain experts work closely with systems analysts and control engineers to produce systems of higher autonomy and efficiency to meet todays global challenge   American Book Publishing Record ,1999   *Neural Networks for Signal Processing* ,2000   *Principles of Data Mining and Knowledge Discovery* ,2000   First International Conference on Artificial Intelligence Applications on Wall Street ,1991   **Developments in Neural Networks and Evolutionary Computing for Civil and Structural Engineering** B. H. V. Topping,1995 Includes a selection of papers presented at the Fourth International Conference on the Application of Artificial Intelligence to Civil and Structural Engineering held at Cambridge England 28 30 August 1995

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