A WWW Based Development Environment for Neural Network Applications in Experimental Physics

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Abstract – *Neural networks are receiving an increasing attention from experimental physicists. Pattern recognition, data analysis and simulation are among the topics that are being addressed by neural processing. To support these applications, WNeural, a WWW based development environment, is being designed. Its modular structure presently covers a number of preprocessing methods for particle and physics channel discriminations and techniques for data analysis with energy measurement detectors (calorimeters). WNeural supports both collaborative project developments and distance learning programmes and it is being used to build connecting bridges on basic science knowledge and modern engineering technology.*

Introduction

Research and development activities are using intensively the Internet network for dissemination of main results and worldwide intercommunication among groups of researchers, including their industrial partners. Moreover, the World Wide Web (WWW) [1] has become very popular as an information repository system. Using browser facilities, the network can be exploited by users who can interact with the information which is stored in remote nodes.

In this paper, the WWW interface is used to develop an user-friend environment for neural processing applications in high-energy experimental physics (named WNeural). In recent years, neural networks enlarged their range of applications in this field, due to their high-performance in pattern recognition and data analysis problems, and their fast response feature that allows online processing applications [2]. As a consequence, a significant number of designs has successfully been accomplished and the number of researchers and students interested on this technique has increased substantially. Thus, developing applications in a WWW based design environment can be quite attractive, as design techniques that proved to be efficient for some application can be accessed and experienced by students and researches wherever they are.

The proposed framework inherently supports distance learning and collaborative research programmes. Particularly, the Federal University of Rio de Janeiro (UFRJ) is very active in neural processing applications in experimental physics and this research is mainly developed in the framework of international collaborations which are based at CERN (European Laboratory for Particle Physics). Therefore, the proposed system can also be very useful to beginners of this research group, as they can learn faster and easier most of the neural network tools and the main features of standard applications. Also, new developments and results can be rapidly accessed by the other collaborators that are spread around the world.

The UFRJ/CERN collaboration has a significant participation of engineers (from the electronics department) and neural network activities are a particular expression of this participation. Therefore, the research in the field of experimental physics is playing a key role in establishing connecting bridges between modern engineering techniques and basic science research. Thus, WNeural helps this connection by means of an exciting interface that allows students to apply neural computation to understand the structure of matter.

In the next section, the scenario of high-energy physics is briefly described and the applications supported by WNeural are highlighted. Then, in the two following sections, the basic structure of WNeural is presented, and current and future educational and research applications of WNeural are discussed. The final section derives some conclusions.

High-Energy Physics

A challenging collider experiment which is under development at CERN is demanding an observation of modern techniques and technologies in order to cope with project specifications. The Large Hadron Collider (LHC) is expected to become operational by the year 2005 and relies on a set of detectors that have been designed over the last ten years and will be entering into industrial production very soon[3, 4].

These detectors will supply diverse information on the resulting interactions from the collisions that will occur with a period of 25 nanoseconds. As most of such collisions do not carry valuable information and only very rare events emerging from this huge background noise will deserve attention in a very demanding offline analysis, an online validation system based on detector information is being developed. This validation system (known as triggering system) involves challenging pattern recognition tasks and parts of the system may be designed by means of neural networks [5].

The detectors included in such complex system comprise different technologies and perform specialized measurements:

- calorimeters measure the energy of the incoming particle and are built from segments that are specialized to electromagnetic (e.m.) or hadronic particles. They absorb entirely the energy of the interacting particles and the deposited energy profiles can efficiently reveal the nature of the particles. In fact, the triggering system mainly relies on calorimeters, due to their pattern recognition abilities and fast response.
- tracking devices provide an image of the interactions near the collision point. These detectors mainly concern the measurement of the momentum of a particle and are also valuable (as they complement the calorimeter information) in the identification of particle classes.
- muon detectors are used to detect muons, which are important particles to the physics being searched for at LHC.

A bunch of neural processing applications has been developed to perform particle discrimination and optimal estimation of detector measurements. The primary focus in the WNeural environment is calorimetry. For calorimeters, the simulation of triggering algorithms based on different preprocessing methods and the estimation of the energy of an incoming particle are being covered. For the other detectors, only global decision designs (that combine information of all participating detectors in the trigger decision) are supported. Global decision schemes are used to identify interesting physics channels and background noise at LHC conditions [6].

The Basic Structure

For a prototype of WNeural, the WWW server interfaces with the repository through CGI (Common Gateway Interface), which contains all the rules and functionalities of the system and allows users to run the applications [7].

Neural simulations are performed by means of a number of codes written in Fortran language that interface with JETNET 2.0 package [8]. An online help facility fully describes the applications.

Two classes of applications are supported: static and dynamic mode applications. For static mode applications, pre-selected parameters and architectures are assumed as default entries by the system. These default settings are optimal values and configurations obtained from the complete design cycle developed beforehand for each application and they allow the user to evaluate the ultimate performance of the neural system on the target application.

In dynamic mode applications, the neural network parameters, configuration and basic architecture may be fully defined by the user. This is a quite interesting manner to develop an application remotely as it allows the user to experience the effects of the main network parameters on the overall performance of the system. For this, a remote user receives a reserved area of the system to run its applications, either in batch mode or interactively.

Common to both modes of running WNeural, experimental and simulation data from detectors and simulated collisions (and resulting interactions with possible detector geometries) at LHC conditions are provided. Also, visualization and performance plots (for both training and production phases of the network) that furnish further insights to the user on system operation are made available. For this, WNeural interfaces with PAW, a software package developed by the physics community and which provides graphical and statistical analysis [9]. Output files that are written at the end of run for a given application supply information to the understanding of the neural network based system responses.

The user has also access to the evolution of the training phase at programmed learning steps. This is very important to evaluate how well the training phase is being realized and, in case of malfunctions originated from a wrong selection of parameter values or even in case the desired development goals are achieved before the completion of the previously programmed number of learning steps, to abort applications.

Multiple accesses to the system from different users are also supported. A user dossier is maintained by the system to monitor the number of users and the login period of each user. The allowable number of users, the timeout for a running user with long inactivity, and the amount of user's allocated memory space depend on computing resources available. User identification is performed by means of a hidden field in CGI.

Presently, pattern recognition and data analysis for scintillating calorimetry are covered by the prototype. Particle discrimination, outsider identification in experimental data samples, feature extraction and triggering system prototypes are among the applications related to pattern recognition. Different calorimeter techniques are studied, among which a scintillating tile calorimeter that will cover the hadronic measurements at LHC [10] and a general-purpose fine-grained calorimeter with longitudinal segmentations that was simulated at LHC conditions [11]. Most of applications make use of topological and principal component analysis to preprocess original input data vectors. This approach not only allows to design more compact classifiers (due to a significant reduction in the dimensionality of the input data spaces), but also usually achieves better performance when compared with raw data based classifiers. For tracking devices and muon detection, pattern recognition is addressed by a combination of simulated classical methods and neural processing for global decision analysis of the triggering system.

Data analysis is performed only for the scintillating tile calorimeter. Here, neural networks are used to perform input-output mapping that aims to optimize the energy resolution and linearity of the calorimeter.

The WNeural environment can be accessed at the address:

http://venus.lacc.ufrj.br:8000/~gustavo/petrus/dneural3.html

WNeural Applications

WNeural is very useful as a supporting tool for teaching neural networks. A previous menu-driven version of this environment was successfully used in an international school in high-energy physics in 1996 [1], which comprised more than 70 graduate and undergraduate students of physics and engineering. The WWW interface will surely increase the range of application of such educational tool that in addition exposes users to modern software engineering techniques. Moreover, as neural processing are applied to physics, WNeural inherently addresses the multi-disciplinary connection between basic science and engineering.

In research, WNeural helps beginners to be introduced to neural network techniques. This is quite important to our activities, as continuously newcomers arrive to our research group. Using WNeural as an introductory tool helps to speedup the time needed to a newcomer to start developing neural network designs. As already said, the interesting feature of remote access of WNeural is also valuable to our cooperative project development that is usually promoted in the framework of CERN based collaborations. In this way, the latest results from neural networks can become available and accessed immediately through the Internet.

WNeural can also be seen as a repository system of well established research applications of neural networks. In this sense, this is a clean documentation facility that can be updated and maintained easily. Also, from its flexibility, WNeural can be expanded as soon as new applications and techniques are developed. Therefore, this repository system can exhibit the state-of-art of our achievements in neural computation.

Conclusions

A WWW based development environment (WNeural) for neural networks was presented. The target applications concern the field of high-energy physics to which neural processing is becoming a standard technique.

WNeural is valuable as a supporting tool for teaching activities in neural networks (both for local and distance learning programmes) and as an auxiliary tool for introducing the main concepts of neural computation to beginners that get involved in research programmes. Applications start from default parameters but can be reconfigured by users, so that deeper experience with network parameters and architectures can be achieved. The user can run interactively or in batch mode.

WNeural is being used in projects developed within the framework of international collaborations. As neural designs are often considered in this framework, WNeural can be maintained and updated in order to exhibit techniques which have been successful in practical applications and tendencies in neural computation research.

Orienting the domain of application of neural computation to experimental particle physics, WNeural offers an exciting and multidisciplinary framework which naturally connects advanced engineering techniques to basic science research.

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