PATTERN MATCHING IN HIGH ENERGY PHISICS BY USING NEURAL NETWORK AND GENETIC ALGORITHM

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Abstract

In this paper two different approaches to provide information from events by high energy phisics experiments are shown. Usually the representations produced in such experiments are spot-composed and the classical algorithms to be needed for data analysis are time consuming. For this reason the possibility to speed up pattern recognition tasks by soft computing approach with parallel algorithms has been investigated. The first scheme shown in the following is a two layer neural network with forward connections, the second one consists of an evolutionary algorithm with elitistic strategy and mutation and cross-over adaptive probability. Test results of these approaches have been carried out analysing a set of images produced by an optical Ring imaging Cherenkov (RICH) detector at CERN.

Keywords: neural network, genetic algorithms, pattern recognition, high energy physics.

1 Introduction

The main effort in the analysis of data obtained in high energy physics depends on the statistical nature of investigated phenomena. The use of optical imaging detectors provides an advanced solutions of the problem but the presence of noise in detected images makes pattern recognition more complicated.
The output produced by optical imaging detectors consists of grey-level images wich record the light stored in each pixel. Several pattern recognition algorithms have been proposed up to now to solve automatically many decision making problem [2], they involved criteria as template matching, detection of similarity and clustering and heuristic, mathematic or syntactic implementative methodologies. Experimental observation of phenomena at subnuclear level requires quanta of high energy. Particle accelerators today achieve energies of the order of the TeV allowing the investigation at distances down 10^{-16} cm. The physics production system can be realized either firing a beam of highly energetic particles toward a fixed target of material or by the collision between circulating beams of highly energetic particles. The resulting secondary particles are observed by a detectors system. Each detector is devoted to explore a feature of the incident particle by an interaction with it to performe the measure process. Pattern recognition techniques can be used to define the feature value as the first step toward the particle identification task. ALICE is an HEP experiment at the Large Hadron Collider at CERN optimized for the study of high energy heavy-ion collisions [1]. A Ring Imaging Cherenkov detector RICH is adopted in ALICE with the aim to identify high-momentum particles in the range from 1 to 5GeV/c. To perform this task, the RICH is able to produce images in which to search for circular regions to charged particles recognition.

2 THE NEURAL NETWORK MODEL

The proposed neural network [6,10] consists of an input and an output layer with feedforward interconnection between them and is based on adaptive linear threshold neurons. The input of the first layer consists of incoming (n x n) binarized images and the output layer designed in order to guarantee the shift invariance of the position of the stimulus pattern consists of a set of m planes where each plane provides (h x h) neurons . In each plane the neurons have the same synaptic spatial distribution and are connected with presynaptic neurons belonging to the

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receptive field so that the relative position among them reflects on the receptive fiel center. The adaptation of network is realised during the learning phase, in order to specialyse an available plane to recognise a noisefree pattern prototype. [6]. The learning process is applied to all the neurons in the same plane using shifted versions of the prototype and provides a response in the [0,1] range, in order to giving the degree of correlation between the stored shapes and the incoming pattern. The task is to train every output plane to recognise m different patterns. The winner takes all strategy is adopted during the recognition phase in order to compute the output of the network . In such a strategy for each plane all the neurons are set to zero except the ones for each the answer yields the largest value.

3 The Genetic Algorithm

The detection of circular regions in RICH images can be view as a search procedure in a suitable solutions space. To implement the genetic search the have been performed. In order to identify a circle into a plan both the coordinates of its center and its radius have been used. These variables have been represented by real numbers and therefore each alleles of a chromosome are to be considered in floating point format. Since, each individual is coded by one chromosome represents a candidate circle, then each chromosome includes three genes each coded by floating point values, representing respectively the coordinates a and b of circle center and the length of circle radius. The initial population is produced by randomly selecting a value for each parameter of individuals with a uniform probability distribution over the range of allowed values.
The fitness function designed involve essentially the two factors available from the experiment, one of geometric kind and the other of energetic one. The dependence of geometric nature has immediately been individualized in the concept of quadratic (squared) distance, penalizing the solutions for which the sum of the squared distances of the spots from the points of the individualized circle was large. The energetic information has been taken into account encouraging those points more bright, weighing the previous distance with energetic intensity of every point. Function used to realise this weighing is shown in the following . It has given good results in terms of convergence and stability.

$$F(a,b,r)=\sum_{i=1}^{N}\left\{\frac{\left[\sqrt{(x_i-a)^2+(y_i-b)^2}-r\right]^2}{\text{intensity}(x_i,y_i)}\right\}$$

where *(a, b) are the co-ordinates of circle center ; r is the length radius circle ; (xi, yi) are the co-ordinate of generic spot; intensity(xi, yi) is the intensity of the considered spot; TRESHOLD is the maximum accepted intensity and N is total number of spots.* In this work it was implemented the selection trough Roulette Wheel Selection, to each chromosome is assigned a probability to be selected proportional to its degree of adaptation. Moreover in order to realise an effective exploration of the search space, a Steady State genetic algorithm with replacement percentage fixed at 25 % has been adopted. The adaptative cross-over and mutation law before mentioned is the following:

$$pCross = pCrossMax - \frac{pCrossMax - pCrossMin}{\text{total iterations number}}(\text{iteration number})$$

$$pMut = pMutMin + \frac{pMutMax - pMutMin}{\text{total iterations number}}(\text{iteration number})$$

2 Application to RICH DATA

The RICH detector is designed with a proximity focusing geometry for particle identification. When a charged particle pass through the radiator, an annular flow of the ultraviolet photons is emitted which is subsequently proximity focused, onto the photon detection plane. The last is a conventional Multi Wire Proportional Chamber with both anode wire and a solid photocatode covered with CsI film. The pads sensitive plane is coupled with the pattern acquisition system. The process for particle identification starts with Cherenkov light emission. When a charged particle pass through the radiator, the active medium of the RICH detector, an annular flow of the ultraviolet photons is emitted which is subsequently proximity focused, onto the photon detection plane. The sensitive plane is coupled with the acquisition system. The process for particle identification starts with Cherenkov light emission and the goal is to measure the radius of the annular light region on the photon detection plane that allows us to distinguish among different classes of charged particles.

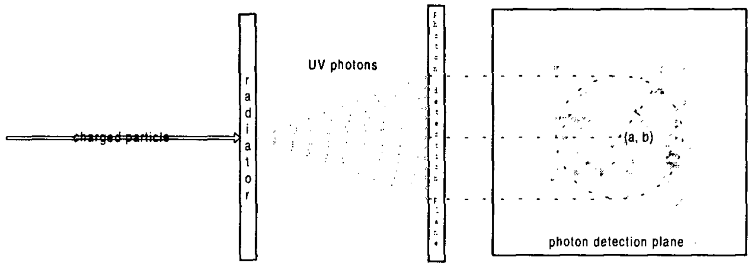

Figure 1: A schematic view of the RICH detector.

4 Test results

The neural network and the genetic algorithm have been implemented on a SISD machine with a software simulation in C language. The neural network parameters consist of an input layer having 171 x 171 dimension, 7 planes of 45 x 45 dimensions each one, receptive field of 111 x 111 dimensions, a 111 x 111 synaptic connections matrix for each neuron in a plane and allows the detection of annular regions radius by the k-th plane with a ranging in R + k x 3 being k = 1,...7.
In order to design the proposed genetic algorithm, 100 simulated RICH images have been taken into account and for each one a session of 50 test runs have been done. For each session the statistical indicators as mean, standard deviation and variance are computed both to choice the best fitness function and to tune parameters of genetic algorithm adopted like mutation and cross-over variability range, population size, maximum number of iterations and rate of overlapping of the populations in the following generations. In figure 3 are shown both a typical simulated spatial distribution of the UV photons as appears onto RICH photon detection plane (left panel), and the theoretical geometric distribution of the spots (right panel). In figure 3 the circle, representing the found better solution, is superimposed on spots distribution.

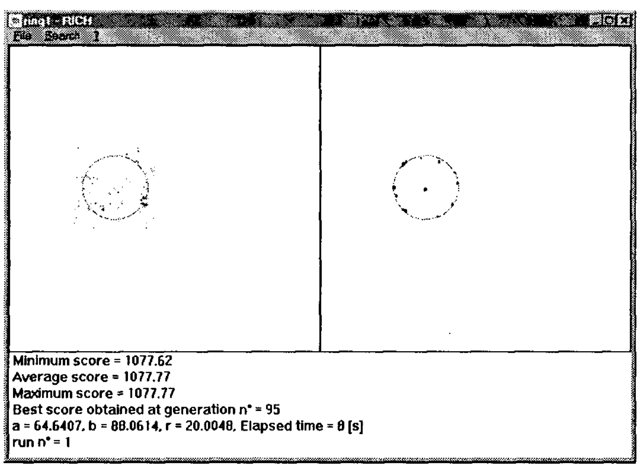

Figure 3. The client area showing the circle detected.

The experimental results obtained by using the proposed algorithms agree with the available theoretical values.

4 Conclusions

In this paper have been studied two algorithms based on intrinsic parallel computation architecture for pattern matching problems in energy physics . The neural network solution is able to recognise additional shapes in a self organising way . This allows the adoption of the network in real time analysis during the physical experiment pattern The evolutionary algorithm takes advantage by a class of the pattern to be detected internal analytic description. This allows a greater precision in pattern detection and then makes this approach more useful in off line data analysis.

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