A neural approach to the analysis of CHIMERA experimental data*

S. Aiello[1], *M. Alderighi*[2], *A. Anzalone*[3], *M. Bartolucci*[4], *M. Bruno*[5], *G. Cardella*[1], *S. Cavallaro*[3,6], *M. D'Agostino*[5], *E. De Filippo*[1], *E. Geraci*[3], *M. Geraci*[1],*F. Giustolisi*[3,6], *P. Guazzoni*[4], *C.M. IaconoManno*[3], *G. Lanzalone*[1,6], *G. Lanzano'*[1], *S. LoNigro*[1,6], *G. Manfredi*[4], *A. Pagano*[1], *M. Papa*[1], *S. Pirrone*[1], *G. Politi*[1,6], *F. Porto*[3,6], *S. Russo*[7], *S. Sambataro*[1,6], *G. Sechi*[2], *M.L. Sperduto*[3,6], *C.M. Sutera*[1], *L. Zetta*[4]

[1] Istituto Nazionale di Fisica Nucleare, sez. di Catania, I-95129 Catania, Italy
[2] Istituto di Fisica Cosmica, CNR, I-20133 Milano, Italy
[3] Istituto Nazionale di Fisica Nucleare, Laboratorio Nazionale del Sud, I- 95123 Catania, Italy
[4] Dipartimento di Fisica dell'Universita' and Istituto Nazionale di Fisica Nucleare, sez. di Milano, I-20133 Milano, Italy
[5] Dipartimento di Fisica dell'Universita' and Istituto Nazionale di Fisica Nucleare, sez. di Bologna, I-40127 Bologna, Italy
[6] Dipartimento di Fisica dell'Universita', I-95129 Catania, Italy
[7] Dipartimento di Fisica dell'Universita', I-20133 Milano, Italy

Abstract

Biological vision processes are at the basis of many studies in the image-processing field. In this context, pre-attentive neural networks developed by S. Grossberg constitute an interesting approach. The paper evaluates the application of Grossberg's approach to the analysis of scatter plots from CHIMERA experimental data. The design and implementation of a pre-attentive neural system developed for this purpose are presented. Simulation results prove the goodness of the approach.

Keywords: data analysis and visualization, neural networks, pre-attentive systems.

1 Introduction

CHIMERA (Charged Heavy Ions Mass and Energy Resolving Array) is a multi-detector operating at Laboratorio Nazionale del Sud in Catania, Italy [1]. It consists of 1192 Si-CsI(Tl) detection cells arranged in cylindrical geometry around the beam axis in 35 rings for a total length of about 4m. The detector allows the identification in charge of the reaction products by means of energy loss (ΔE) and residual energy measurements (E). In addition, the systematic measurement of the time of flight allows velocity and mass determinations. Finally, the use of Si-CsI(Tl) detectors makes it possible to discriminate light particles (Z=1, 2, 3) by means of pulse shape analysis techniques.

Preliminary analysis of CHIMERA experimental data is performed on two dimensional (2-D) matrices, or scatter plots, representing the measurement of the aforementioned quantities. When visualized, these pictures contain clusters, each corresponding to a reaction product, that have to be extracted in order to obtain the necessary information for the identification of all detected ions. Generally, matrices are sparse and their data characterized by a low signal-to-noise ratio. In addition, great variations of both point density and signal-to-noise ratio can be observed in a matrix. Complexity of matrices does not favor the use of algorithmic approaches for the identification of clusters. Indeed algorithmic approaches are difficult to specify because of the sparse nature and noise. Nevertheless, clusters can be easily perceived and recognized by sight. This has suggested using the same mechanisms that in biological visual systems allow for emergent perception, i.e. the extraction of hidden information that is present in a context but is not explicitly expressed.

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S. Grossberg, in his work on biological vision modeling, developed pre-attentive neural networks as a model of emerging perception processes [2]. They are able to extract meaningful information from the global structure of data rather than from local relationships, yielding to a coherent and complete visual perception, also in case of noisy and incomplete images. This approach has been widely and successfully used in the processing of SAR and satellite images [3], but can also be of great interest in many other fields in which 2-D representations that can be considered as images are used for data analysis.

This paper is concerned with the application of Grossberg's approach to the analysis of 2-D matrices from CHIMERA experimental data. A pre-attentive neural system was designed and implemented for this purpose. The implementation was accomplished using the Matlab language. Section 2 briefly reviews the experimental context of our application. Section 3 describes the implemented system and discusses the results obtained. Conclusions are drawn in Section 4.

2 Experimental context

CHIMERA detection results are represented by means of 2-D matrices representing physical quantities measured in the detection cells. Each particle, or ion, is located at a point of the matrix depending on its nature (mass and charge) and velocity. Matrices can be filled by thousands of such events, some of them cumulating at the same location. When sufficient statistics is collected, matrix visualization shows a picture of ridges (Z-lines) and valley, each ridge corresponding to a given type of ion, mostly determined by its charge Z. In order to identify all detected ions, physicists have to recognize all the particles belonging to the same class, that is the same Z-line. In this sense, the identification problem becomes a classification problem. Classification of Z-lines is generally performed manually. A human operator extracts, for each spectrum, the points corresponding to each Z-line. An alternative unsupervised technique based on a sophisticated image segmentation algorithm employing a priori information is illustrated in [4]. The manual technique could be acceptable in old generation detectors, for which a low number of spectra were usually produced. Given the number of scatter plots now produced in a typical experiment (roughly thousands), automatic methods for particle identification are highly desirable.

3 Implementation

The implemented system processes the data, an example of which is shown in Figure 1a, and produces the related frequency identification spectrum in automatic way. The system is composed of two main parts: one neural aimed at classifying the points in (ΔE, E) matrices, and the other, based on a classical procedural algorithm, applying an isomorphic transformation of representations, as to produce monodimensional frequency representations. Points are classified as belonging or not belonging to a cluster. This is achieved by providing, as output of the neural processing, images in which clusters of points are replaced by strips, that is areas whose pixel values are set to "1" and matching the hyperbolic shape of the original clusters. The initial matrix is broken down in submatrices that constitute the processing windows on which the neural system operates, e.g. Figure 1b. Dealing with windows of fixed dimensions allows to process different windows in parallel, thus improving performance. It was empirically found that windows of 500x500 pixels contain sufficient information for classification and show homogeneous characteristics of their elements.

3.1 Neural processing

The system is a hierarchical architecture consisting of two levels of neural networks. The second-level networks receive as input the images resulting from the first-level networks, which in turn process the original image windows. Networks are composed by 500x500 neurons, each neuron corresponding to a single pixel. Input and output images have the same dimensions. The first-level network performs an Adaptive Density Discrimination (ADD) of the original image window, while the second-level networks realize an oriented completion of the structures determined by the first-level networks, by means of a Bipole Filter (BF) as neuron receptive field. These two levels implement a subset of the rules defined in Grossberg's Boundary Contour System (BCS) [2, 3]. Classically these rules are applied in order to reveal boundaries in images. In our approach we identify structures (clusters) as a whole, rather than their boundaries. This makes processing less sensitive to fluctuations of the local densities of data points in the matrices. In our application clusters depict a hyperbolic shape with a slow evolving slope, showing a constant inclination angle in processing windows. In this way they can be revealed as quasi-parallel strips. Figure 2a shows the output of the ADD level, while the whole neural processing output is shown in Figure 2c. Details of the neural system are given in [5].

3.2 Post neural processing

This processing consists in a series of Matlab procedures that determine the borders of the strips identified in the neural stage, compute the central lines (Z-lines) of filled strips and finally apply the linear isomorphism to the original data representation for final spectrum construction. This implies transforming the coordinates (ΔE, E) of each point of the original scatter plot according to the linear transformation reported in [4]. The Z-lines of the clusters in the selected image window are highlighted in Figure 1b. Figure 2b displays the result of the coordinate linear transformation for the same window. The frequency distribution spectrum is given in Figure 2d, which clearly shows the peaks corresponding to the different charges of the detected ions.

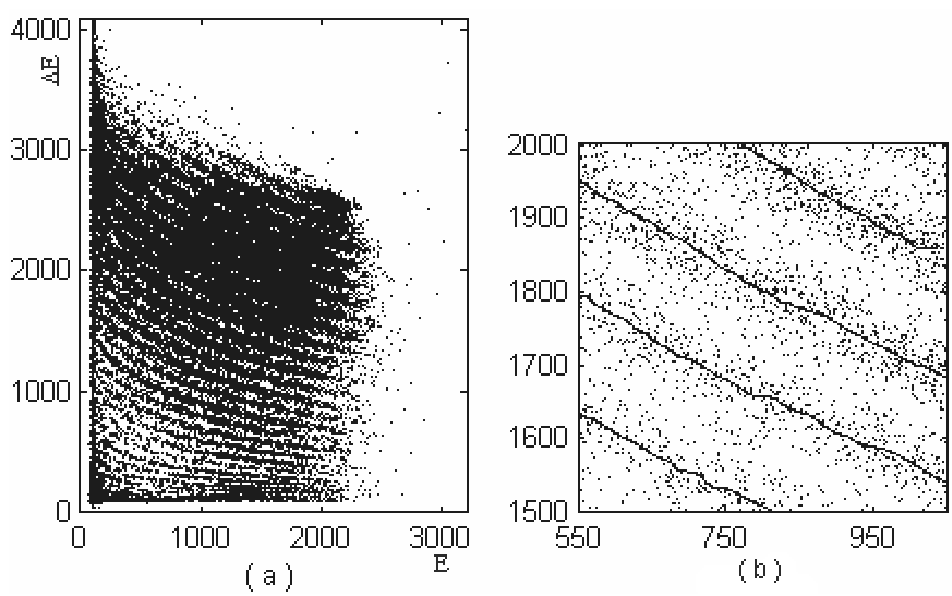

Figure 1: (a) Input scatter plot for the reaction ^{58}Ni + ^{27}Al, E_{Inc} = 30 AMeV. (b) Selected processing window.

4 Conclusions

A pre-attentive neural system, based on Grossberg's perceptive visual system model was developed and implemented for the analysis of nuclear physics experimental data. Results obtained proved the goodness of the chosen approach. In the short term we plan to make the system able to handle 4096x4096 pixel matrices directly, by processing different image windows in parallel.

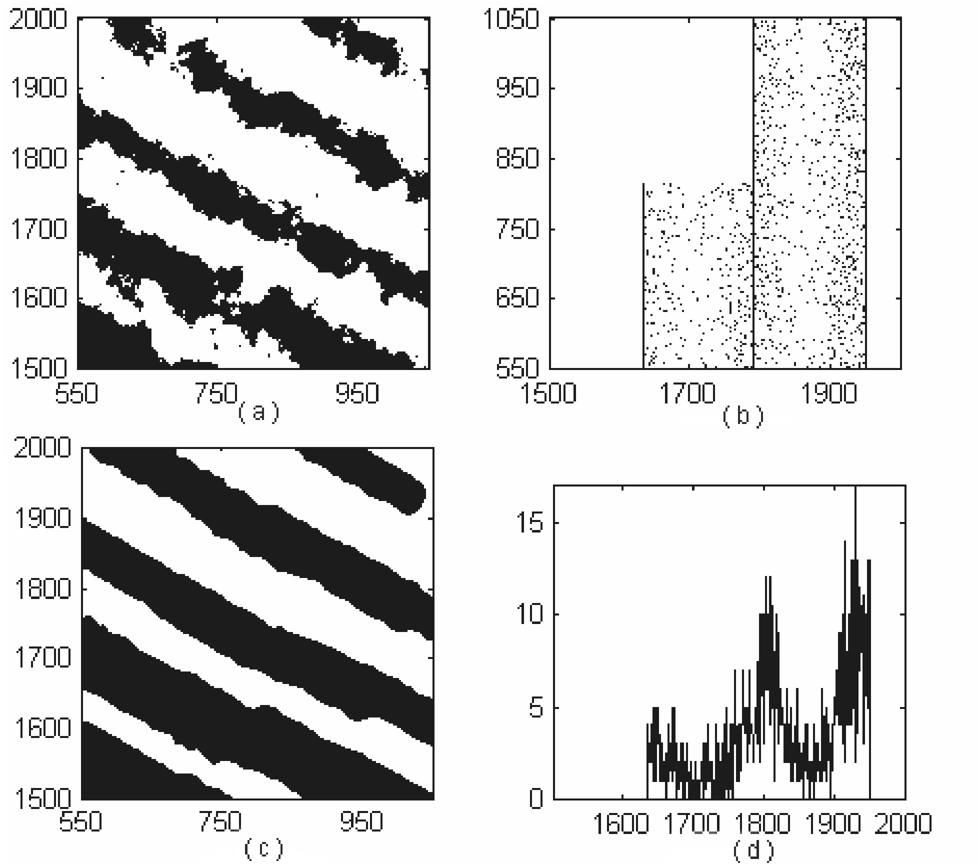

Figure 2: (a) ADD level output. (b) Coordinate linear transformation result. (c) Neural system output. (d) Frequency distribution spectrum.

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