J-Net System: a new paradigm for Artificial Neural Networks applied to diagnostic imaging

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Abstract - In this paper we present a new unsupervised artificial adaptive system, able to extract features of interest in digital imaging, to reduce image noise maintaining the spatial resolution of high contrast structures and the expression of hidden morphological features. The new system, named J-Net, belongs to the family of ACM systems developed by Semeion Research Institute. J-Net is able to isolate in an almost geological way different brightness layers in the same image. These layers seem to be invisible to the human eye and for the other mathematical imaging system. This ability of the J-Net can have important medical applications. Two examples of application are reported: the first in digital subtraction angiography for arterial stenosis diagnosis and the second in Multi-slice CT for lung cancer early detection and evolution prediction.

Keywords: Image processing, Artificial Neural Networks, Active Connections Matrixes

I. INTRODUCTION

Significant progress in the development of machine vision and image processing technology has been made in the past few years in the medical field in conjunction with improvements in computer technology [1-9].

With the introduction of multi-slice spiral CT scanners, the number of images of body organs, like the lung for example, is steadily increasing and it is critical to develop fast, accurate algorithms that require minimal to no human interaction to identify emergent features of interest.

Artificial neural networks (ANNs) can overcome some of these difficulties by interpreting images quickly and effectively. ANNs are composed of numerous processing elements (PEs) arranged in various layers, with interconnections between pairs of PEs [10, 11, 12]. They are designed to emulate the structure of natural neural networks such as those of a human brain. For most ANNs, PEs in each layer are fully connected with PEs in the adjacent layer or layers, but are not connected to other PEs in the same layer. The PEs simulate the function of the neurons in natural neural networks, while the interconnections between them mimic the functions of dendrites and axons.

There have been many applications of ANNs reported for the interpretation of images in medicine.

The main problems in many image processing applications still are the abundance of features and the difficulty of coping with concomitant variations in position, orientation and scale. This clearly indicates the need for more intelligent, invariant feature extraction and feature selection mechanisms [13]. In a recent review about the role of ANNs in medical decision support with digital imaging the authors concluded that ANNs can play a role in image processing, although it might be a role as a supporting tool rather than a major one [14, 15, 16, 17].

The Active Connection Matrix (ACM) is a new unsupervised artificial adaptive system developed by Semeion Research Institute [18]. The system is able to automatically extract features of interest (e.g. edges, tissue differentiation, etc.) from digital images when activated by original non linear equations. ACM systems copy with the features selection problems in digital imaging: ACM activation allows the reduction of image noise while maintaining the spatial resolution of high contrast structures and the expression of hidden morphological features.

The general philosophy and mathematical background of ACM systems are described in the paper of this special session “Four Models for four medical applications” by Massimo Buscema.

II. MEDICAL APPLICATIONS OF J-NET, A NEW ACM SYSTEM

The aim of the current study is to describe potential applications of J-Net System, a specific system of ACM family, as a support for accurate diagnosis in digital subtraction angiography of popliteal artery and for differentiating between benign and malignant pulmonary nodules identified by MDCT scanners.

J-Net considers each image as a Active Connections Matrix, where each node is linked to its nearest neighbours, trough adaptive weights. During the processing phase J-Net modifies its global weights matrix and the state of each node (pixel), according to a specific cost function, considering only the assigned image.

J-Net Image Processing enhances possible differences in the burden of the lesion through a deterministic algorithm which extracts morphological (not noisy) features hidden to human eyes.

The detailed notions of equations and function of J-Net system is described in the paper of this special session “Four Models for four medical applications” by Massimo Buscema. Before deciding to apply J-Net system to medical images we have assessed its ability to extract the outline of an image in few cycles in different toy models with noisy images,