CT IMAGE SEGMENTATION BY SELF-ORGANIZING LEARNING

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Abstract

In this paper we approach the segmentation of tibia CT images using a self-organizing feature map. This type of Artificial Neural Network carries out a competitive learning process which permits the discrimination of different structures found in the images with sensitivity to changes in the distribution and value of the gray levels of the pixels. The results obtained show that this technique is adequate for the segmentation of images with complex structures and a low signal/noise ratio.

Introduction

The segmentation of an image is a basic problem in automatic image analysis systems. Segmentation consists in the division of an image into a set of homogeneous elementary regions. In this work we approach the segmentation of tibia computational tomography (CT) images aimed at the three dimensional reconstruction of the structure. In order to do this we analyze a sequence of slices which correspond to transverse sections of the bone. The final objective is the automatic construction of a patient specific 3D model of the tibia using finite elements. Given the fact that the configuration of these elements is of paramount importance for a correct dynamic simulation of the structure when it has to withstand stresses, these elements must respond to the elementary region distribution. Their mechanical properties are related to the densitometric properties of the regions. It is therefore important to obtain a detailed and precise segmentation of each slice and consequently, of the global structure.

A large quantity of strategies for approaching the segmentation process can be found in the literature on the topic. They respond to two basic ideas: detection of local discontinuities (edge/boundary detection) or detection of local areas with homogeneous properties (amplitude and clustering segmentation, region growing) (Pratt, 1991). However, given the complexity of the structures in this type of images and their low signal to noise ratio, these classical segmentation techniques produce poor results when applied to them. In order to solve this problem, we present an alternative scheme based on the use of the self organizing topological maps proposed by Kohonen (1982). Several authors suggest employing these connectionist structures for the segmentation of medical images obtained by means of ultrasounds (Silverman, 1991) or magnetic resonance (Springub et al, 1991). On the other hand, the results would be better if instead of basing the segmentation only on the intensity of the pixels, their spatial properties were also taken into account. For this, each pixel is characterized by means of a feature vector whose components are the gray levels of the pixel and of its neighbors in the image plane, if we process a single slice, or in space if we process the whole 3D structure. The segmentation problem is thus transformed into a problem of classifying a set of n-dimensional feature vectors. Using a competitive, non supervised, learning process the neural structure generates a topological map which responds to the structures found in the data set. In our case, this map is a linear structure with J units, where each unit contains an n-dimensional vector. Each point of the feature space corresponds to the nearest point (class) in the generated map. The elementary regions resulting from the process arise when this information about classes is transferred to the image space: adjacent pixels whose feature vectors are projected onto the same unit will make up an elementary region. The preliminary results obtained for tibia CT images evidence the validity of the structure we propose.

Methodology

Material

In order to approach the global problem of the automatic construction of a patient specific three dimensional tibial model we use a sequence of 24 contiguous transverse CT scan proximal tibia slices obtained in vivo by means of a scanner operating under the following conditions: 120 KVp, 200 mA, 3.7 ms exposure and 2 mm slice thickness. These images were obtained with 256 gray levels, a 180*180 pixel spatial resolution and a pixel size of 0.71 mm^2.

Our initial objective was to determine both the perimeter (external cortical, inner cortical and bone thickness) and bone morphology. For this, we have processed these images slice by slice using the Artificial Neural Network (ANN) and the procedure we describe below.

Self-organizing feature map

We consider a self-organizing feature map made up of J neurons. Each neuron N_j, receives the pixels of a window or partial area of a tibia CT image as inputs. We represent this window by means of a vector $P=\{p_1,...p_I\}$, where each element p_i represents the gray level of the i-th pixel of the window. Each neuron N_j receives the values p_i as inputs modulated by a weight vector $W_j=\{w_{1j},...w_{Ij}\}$, where w_{ij} is the weight associated with the i-th input to neuron j. This way, when a input P is applied to the network, an output vector $O=\{o_1,...o_J\}$ is obtained. The component o_j, output of the j-th neuron, is:

$$o_j = (P - W_j)^T * (P - W_j) \quad (1)$$

Therefore, the neuron with the lowest output value will be the one which will better "correspond" to the pattern or window used as input to the network. Figure 1 shows the structure of the network.

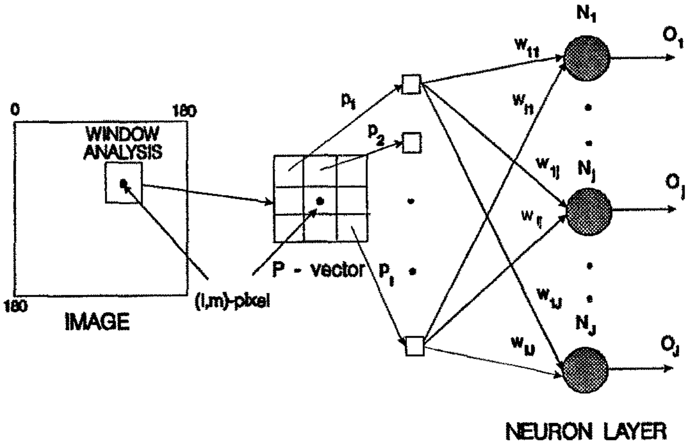

Figure1. Structure of the network

The training process in this type of AANs produces an adjustment of the weight vectors associated with the different neurons of the network. This training process is aimed at making the neurons sensitive to the different