Bone Spect Image Segmentation Based on the Hermite Transform

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Abstract. Nuclear medicine image technology is currently an important modality for medical diagnosis whose applications have been extended for evaluation of a high number of human diseases. In this sense, SPECT (Single Photon Emission Computed Tomography) is one of the most used types of medical images in the field of nuclear medicine. In this work, we present a method for the segmentation of bone SPECT images. The proposed method is based on a region growing scheme implemented in the domain defined by the Hermite transform (HT) which consists of a mathematical tool that decomposes an image into a set of image coefficients representing a set of features. The method uses the coefficients obtained through the HT with the objective of designing a growing criterion that allows the segmentation of the needed region. The designed approach is focused on segmenting the bone structures in SPECT images. We evaluated the proposed scheme using several bone SPECT images. Different metrics have been also used for performance assessment.

1 Introduction

SPECT image modality is part of the nuclear medicine technologies which is commonly used in the field of radiology. This type of medical images has become essential for illness detection and treatment. It uses a set of photons generated by radioactive isotopes that have been previously injected into the human body. When the radiopharmaceutical substance interacts with the tissues, the photons are produced, and they must be captured by a gamma camera, providing a set of image slices with the information of the organ of interest. It must be noted that with this technology we can gather metabolic information of the corresponding tissues [1]. Currently, the SPECT technology is vastly used for many applications of disease detection and diagnosis, including evaluation of the bone conditions [2]. The intensity levels coded in the SPECT images quantify the uptake of the radioactive isotope performed by the evaluated tissue, and it is an indicative of the patient conditions. SPECT, nonetheless, presents huge limitations because the spatial resolution and the contrast of the resulting images are poor.

On the other hand, quantification and assessment of the tissues of interest are tasks that might help in the diagnosis procedure, which can be carried out by using

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segmentation algorithms. The poor contrast and resolution of SPECT images hinder the correct extraction of the tissue boundaries, even for nuclear medicine physicians. In the literature, we can find several segmentation algorithms which have been designed to be applied to nuclear medicine images [3–5]. Active shape models [3], clustering-based methods [4], level sets [5] and machine learning approaches have been employed for this task [6]. Given the limitations found in this type of medical images, the segmentation problem remains open, even more when analyzing bone tissues.

In this work, we present a segmentation method based on the Hermite transform and a region growing scheme. The latter is implemented into the HT domain. Hermite coefficients are used for the design of the growing criterion. It has been demonstrated in several works, the efficiency of the HT for representing different types of image features [7]. Our method is evaluated using several SPECT image examples acquired for evaluating the bone structures.

2 Methodology

In this section, we introduce the designed scheme. Let $f(x,y)$ be an input image. The HT is calculated as [7]

$$L_{n-m,m}(p,q) = \int\int_{-\infty}^{\infty} (x,y)V^2(x-p,y-q)G_{n-m,m}(x-p,y-q)dxdy \qquad (1)$$

where $L_{n-m,m}(p,q)$ are the cartesian Hermite coefficients, $V(x,y) = \frac{1}{\sigma\sqrt{\pi}} e^{-\left(x^2+y^2\right)/2\sigma^2}$ is a Gaussian window and $G_{n-m,m} = \frac{1}{\sqrt{2^n(n-m)m!}} H_{n-m}(x/\sigma)H_m(y/\sigma)$ are the normalized Hermite polynomials [7]. The transform order is determined by n. Coefficients must be computed for $n = 0, 1, 2, \ldots, N$ and $m = 0, 1, \ldots, n$. For $n = 0$, low frequency components are obtained, and details coefficients are calculated when $n \geq 1$. Until order $n = 2$, coefficients code features such as intensity, edges and zero crossing. These texture coefficients are then used to build the region growing scheme. Figure 1 presents cartesian Hermite coefficients up to second order applied to an image of nuclear medicine.

At the beginning, we need to provide an initial seed point. Therefore, information gathered from the neighborhood of that point is used to classify the rest of pixels. This information is evaluated using the texture coefficients obtained with the HT. The algorithm is iteratively run until a stable condition is reached which generates the segmentation of the desired bone structure. In general, the proposed method consists of two steps: (1) The HT is calculated, and (2) The region growing technique is applied using information from the Hermite coefficients. The classification criterion is configured based on the homogeneity found in the HT coefficients. The following growing rule is used.

$$C(p,q,r) = L_{m,n-m}(p,q) - L_{m,n-m}(p^r,q^r) \qquad (2)$$

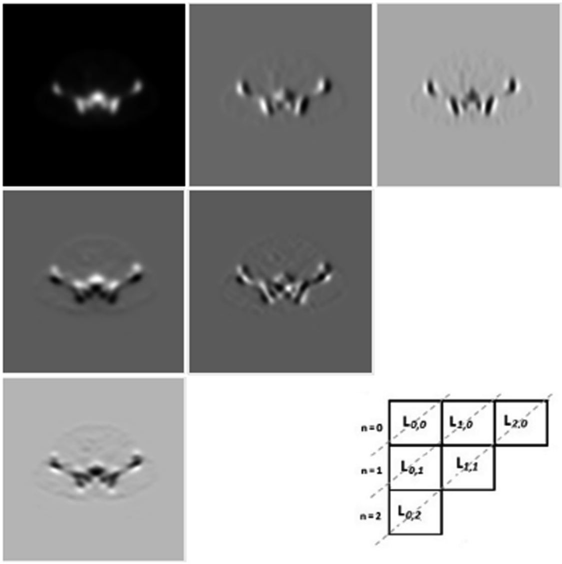

Fig. 1. Hermite transform up to order 2.

where $L_{m,n-m}(p,q)$ represents the Hermite coefficient value at point (p,q), and $L_{m,n-m}(p^r,q^r)$ corresponds to the average value computed from the neighborhood of that point. The variable C measures the homogeneity between the current point and its neighborhood. Therefore, C must be then thresholded to decide if that point corresponds to the desired object. In addition, 4 or 8 connectivity must be considered.

This method is used to provide a robust scheme that takes advantage of three types of image features.

3 Results

Examples of SPECT images were used for performance evaluation. The seed point is, until now, manually selected. The HT is computed for a second order. The growing algorithm is proved using 8 connectivity. Some results using the proposed segmentation method are illustrated in Fig. 2. It can be seen that the desired bone is satisfactory extracted.

Quantitative analysis presents the segmentation results using classical region growing and the model combining the HT and the region growing. For the evaluation we used a total of 20 images corresponding to 2 patients (Table 1).

The HT with region growing is a simple method able to achieve efficiently the contour in images of nuclear medicine. The method proposed in this work presents improved results than classical region growing. The coefficients of HT include more information of the original image which they are different texture useful in the segmentation process. The implementation scheme can be employed in the analysis of bone abnormalities.

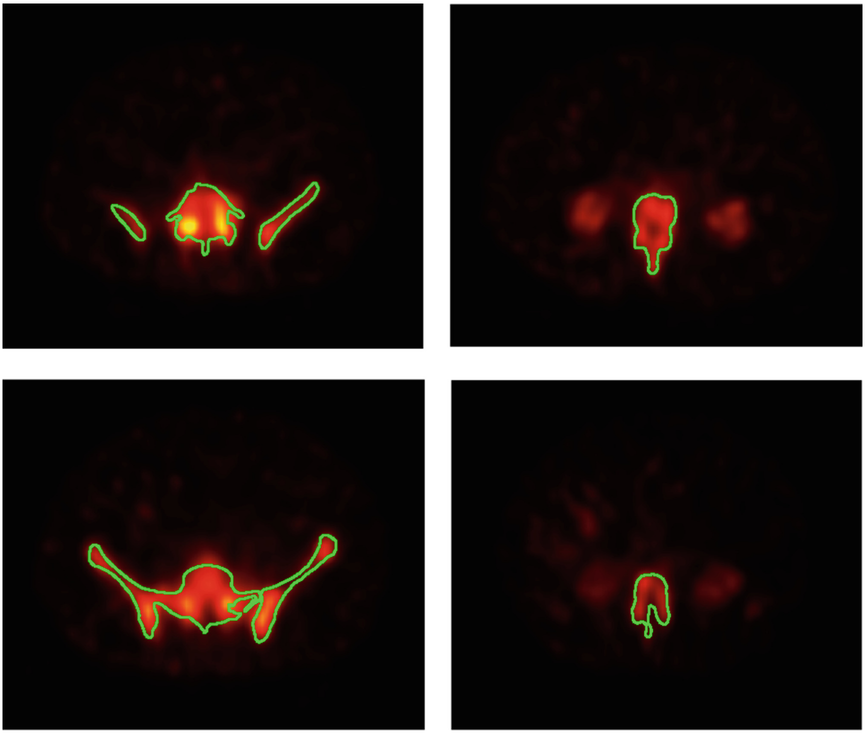

Fig. 2. Example results of the segmentation process obtained with the proposed method. The green contour corresponds to the boundary of the segmented object.

Table 1. Average point-to-curve distance obtained for 2 patients.

Patients	Images	Classical region growing	The HT with region growing
1	11	7.32 ± 3.25	3.96 ± 2.73
2	9	8.67 ± 4.50	5.01 ± 3.02

4 Conclusion

We developed an image segmentation scheme based on the Hermite transform and a region growing approach. It was applied to analysis of SPECT images. The region growing criterion is evaluated using the Hermite coefficients which allow to code several image features to improve the selection process. The method can be efficiently used for extracting the bone tissues in SPECT images.

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