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## Original Research Article

## Fractal analysis of the grey and binary images in diagnosis of Hashimoto's thyroiditis

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## ABSTRACT

In the study, a fractal analysis of thyroid ultrasound images was applied. This method has not been too often used for testing such kind of images so far. Its advantage is a tool in a form of a fractal dimension, which easily quantifies a complexity of an image texture surface. There is a close relationship between the lesions and an ultrasound image texture in a case of a diffuse form of the Hashimoto's disease. As a result of the analysis, a set of nine fractal descriptors was obtained which made it possible to distinguish healthy cases from sick ones that suffer from the diffuse form of the Hashimoto's thyroiditis. The Hellwig's method for feature selection was utilised. It found the combinations of features of the highest value of the information capacity index. These combinations were applied to build and test five popular classifiers. The following methods were implemented: decision tree, random forests, K-nearest neighbours, linear and quadratic discriminant analysis. The best results were achieved with a combination of three descriptors – fractal dimension and intercept obtained by the power spectral density method and fractal dimension estimated by the box counting method. The LDA (linear discriminant analysis) classifier based on them was characterised by a sensitivity of 96.88%, a specificity at a level of 98.44%, and its overall classification accuracy was equal to 97.66%. These results are similar to the best results of other authors cited in the work where the greyscale image analysis was used.

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## 1. Introduction

Hashimoto's thyroiditis is one of the more common thyroid ailments. It is related to disorders of the body's immune system, but its causes are not well known. It is the most common cause of hypothyroidism, and the most common type of thyroiditis. The disease manifests itself in the form of characteristic inflammatory lesions. They may take a diffuse

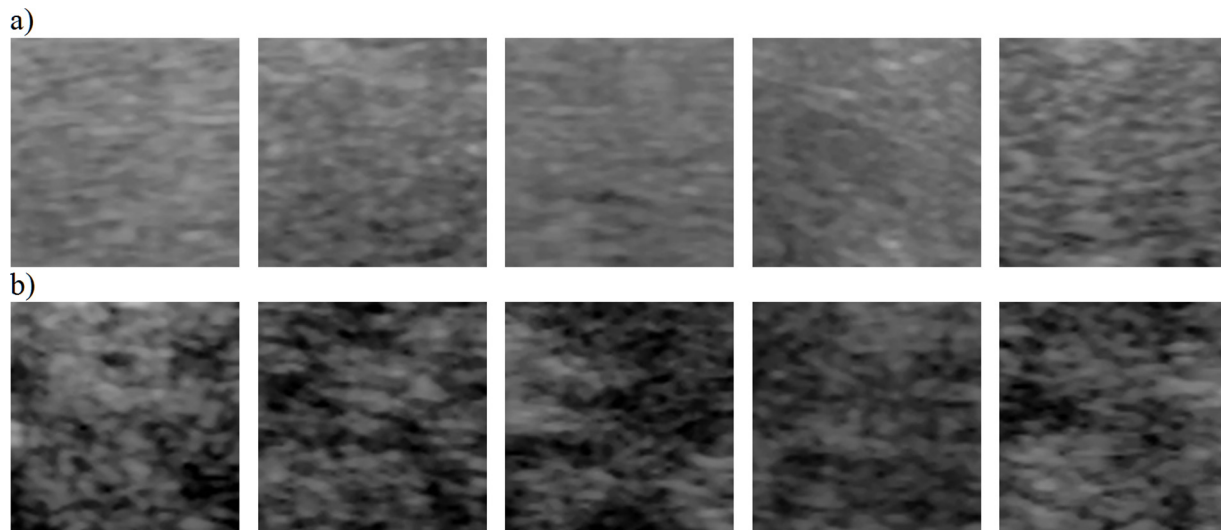
or focal form. The diffuse form encompasses the entire thyroid or its significant part. The gland suffering from inflammation enlarges gradually to form a goitre that is usually symmetrical, hard and has a more or less smooth surface. This ailment is usually diagnosed from the age of 30 to 50. Usually, it is already in an advanced form, hypothyroidism occurs and implementing appropriate treatment is very difficult. It is important to diagnose the disease as early as possible, because applying proper treatment procedures as soon as possible increases the

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**Fig. 1 – Examples of regions of interest for two analysed categories: (a) healthy cases (homogeneous tissue and normal echogenicity); (b) sick cases (heterogeneous tissue and hypoechogenicity).**

effectiveness of therapy. The primary method for initial diagnosis of the Hashimoto's thyroiditis is ultrasonography, however such a diagnosis based on ultrasound images is a very difficult task. In this paper, the results concerning the diffuse form of the disease are presented. In such a case, a typical ultrasound image shows the tissue heterogeneity and reduced echogenicity of a substantial parenchyma part (Fig. 1).

There are relatively few papers presenting results referring to the diagnosis of the Hashimoto's thyroiditis based on the thyroid textured images. Some of them use a simple greyscale image analysis [1-5]. Another ones implement more advanced procedures for texture analysis [6-14]. There are also interesting articles presenting the results of distinguishing benign and malignant thyroid nodules [15-20]. In the case of nodules, the disease has a focal form. This work presents results concerning not nodules, but the diffuse form of the Hashimoto's disease. However in both cases, similar methods for ultrasound image processing, analyzing and classifying may be used, especially if the subject of study is the image texture. A shortcoming of the earlier-cited works is that most of them give a general classification accuracy without detailed information on the sensitivity and specificity. It is therefore difficult to rate the relationship between these two parameters. A fractal analysis of the grey and binary images in this work was applied. This method is often used for the analysis of biomedical images, but the author is not aware of too many results of its utilisation for the diagnosis of a diffuse form of the Hashimoto's disease based on the analysis of ultrasound images. One of the few known results was presented in [9] where the authors applied the modified differential box counting method to calculate a fractal dimension. Another results are described in [17], where fractal texture and spatial grey level dependency features were used for the classification of thyroid lesions. The proposed systems employ a fractal descriptor obtained by one specific analysis method. Besides, it is not used alone but in combination with other descriptors. A novelty of this work is to show that the discussed system may

be based on several descriptors, selected solely on the basis of fractal analysis.

A computer representation of a medical image (e.g. radiological or ultrasound) is an image matrix of size  $M \times N$ , where  $M, N$  are the numbers of rows and columns of the image. Elements of this matrix correspond to greyscale levels of image pixels and form a more or less complex surface. A fractal analysis tool in a form of the fractal dimension to assess this complexity may be used. It makes it possible to easily quantify the smoothness and regularity of the surface. Compared to the healthy cases, ultrasound images of patients affected by the diffuse form of the Hashimoto's disease are characterised by the increased tissue heterogeneity and hypoechogenicity of a substantial parenchyma part (Fig. 1). These changes are reflected in a complexity of the ultrasound image surface. Thus, to quantify the pathological changes in the gland tissue, the above-mentioned fractal dimension can be used. Statistical analysis confirmed the significance of differences in mean values of this parameter for the cases of healthy and sick patients. Values of the fractal dimension are in the range of 2-3 for the grey thyroid ultrasound images. In the study, the fractal dimension was also estimated based on the binary images. In this case, its values are in the range of 1-2. The binary images were also used to calculate the lacunarity. In addition to the use of the fractal analysis for diagnosis of the diffuse form of the Hashimoto's disease, a new approach presented in the work is also the simultaneous use of descriptors of grey and binary images during the classification process. The fractal analysis allowed to obtain nine diagnostic indicators. Based on them, classifiers using five popular classification methods were built. They made it possible to classify the analysed cases into one of two groups: sick or healthy. Classification quality was evaluated using the three measures – sensitivity, specificity and a general classification accuracy. As a result, the LDA classifier built based on the three fractal descriptors was chosen. Its sensitivity, specificity and overall classification accuracy were equal to 96.88%, 98.44% and 97.66% respectively.

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