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Small lung nodules detection based on local variance analysis and probabilistic neural network

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ABSTRACT

Background and objective: In medical examinations doctors use various techniques in order to provide to the patients an accurate analysis of their actual state of health. One of the commonly used methodologies is the x-ray screening. This examination very often help to diagnose some diseases of chest organs. The most frequent cause of wrong diagnosis lie in the radiologist's difficulty in interpreting the presence of lungs carcinoma in chest X-ray. In such circumstances, an automated approach could be highly advantageous as it provides important help in medical diagnosis.
Methods: In this paper we propose a new classification method of the lung carcinomas. This method start with the localization and extraction of the lung nodules by computing, for each pixel of the original image, the local variance obtaining an output image (variance image) with the same size of the original image. In the variance image we find the local maxima and then by using the locations of these maxima in the original image we found the contours of the possible nodules in lung tissues. However after this segmentation stage we find many false nodules. Therefore to discriminate the true ones we use a probabilistic neural network as classifier.
Results: The performance of our approach is 92% of correct classifications, while the sensitivity is 95% and the specificity is 89.7%. The misclassification errors are due to the fact that network confuses false nodules with the true ones (6%) and true nodules with the false ones (2%).
Conclusions: Several researchers have proposed automated algorithms to detect and classify pulmonary nodules but these methods fail to detect low-contrast nodules and have a high computational complexity, in contrast our method is relatively simple but at the same time provides good results and can detect low-contrast nodules. Furthermore, in this paper is presented a new algorithm for training the PNN neural networks that allows to obtain PNNs with many fewer neurons compared to the neural networks obtained by using the training algorithms present in the literature. So considerably lowering the computational burden of the trained network and at same time keeping the same performances.

1. Introduction

Lung cancer is most curable when detected at an early stage. Unfortunately, the majority of individuals discover the presence of the lung cancer at an advanced stage, when the prognosis is very poor. The major goal of any screening program is a reduction in the number of disease specific deaths in the screened population.

The principle of the x-ray methods require radiation source, which generates the waves with length ranging from 10 pm to 10 nm, and detector. Radiation with these properties penetrate our body. Different tissues have different absorption capacity, when x-ray burst of radiation passes through the body and strikes a detector. Body parts with higher density are presented as structures (i.e. bones). In contrasts, tissues with lower density such as lungs have darker reflection in the image. As a result, bones appear white, soft tissues show up in shades of gray and air appears black. The

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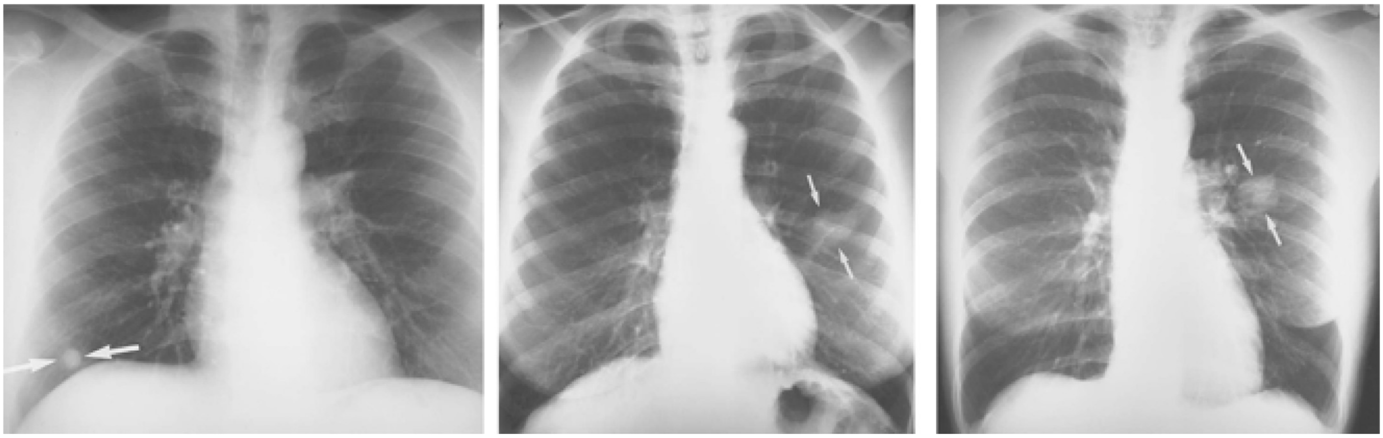

Fig. 1. Samples of lung x-ray images, where pulmonary nodules were detected. Images with detailed description are available at http://radiologykey.com/solitary-and-multiple-pulmonary-nodules/.

dose of radiation used in x-ray is about 0.02 [mSv] for a front view and 0.08 [mSv] for a side view. Modern x-ray systems have well-controlled x-ray beams and doses minimized to stray (scatter) radiation. In Fig. 1 are shown some samples of chest x-ray with diagnosed nodules in lungs.

Chest x-ray screening for lung carcinoma (radiography performed to detect pre symptomatic disease) is the most important tool for the prevention. Unfortunately, the early detection and interpretation of lung carcinoma using chest X-ray is achieved in ≈30% of cases. A very important fact is that, in 90% of peripheral neoplasms and in 65–70% of central neoplasms, there was radiographic evidence many months before the malignancies actually were diagnosed.

The most frequent cause of detection failure is the radiologist's difficulty in interpreting the presence of lungs carcinoma in chest x-ray. In fact is very hard evaluate unclear zones that are very opaque and may have scarcely defined margins or may be hidden totally by superimposition of other structures, particularly bones.

Due to the high prevalence of lung cancer among total cancer cases and the high mortality rate of the disease post-diagnosis, the prevailing thought is to identify visible nodules before they metastasize in order to dramatically reduce the death toll.

The in-depth interpretation of the chest x-ray requires a subtlety that may not be immediately obvious in many circumstances. In such circumstances, an automated approach could be highly advantageous as it provides important help in medical diagnosis.

In this paper we propose a new classification method of the lung carcinomas, based on a simple segmentation method and on a probabilistic neural network in order to obtain a more accurate classification of the presence or absence of lung carcinomas in chest x-ray image. The proposed method presents good performances obtaining an overall correct classification rate of 92%.

1.1. Related works

The analysis of the consequences from the untreated symptoms that may lead to cancer were presented in [1,2]. In these papers are reported the recent advances in automated detection of abnormalities in lungs were reported. An approach based on radiomic features provided by Support Vector Machine was presented in [3], while in [4] a model of pulmonary nodules detection based on the analysis of significant features in x-ray images was presented. In [5] the possible nodules were extracted by using a polygon approximation. A comparative analysis of various approaches are discussed in [6]. The neural networks play an important role in classification of lung tissues abnormalities. In [7] was presented a fusion of deep learning approach used for evaluation of nodules from texture and shape analysis. While in [8], Zhang et al. [9] are used a Convolutional Neural Network and an Extreme Learning Machine, respectively, for classification of lung nodules. Furthermore, adaptive models of neural networks have been developed [10–12]. A comparative analysis on a wide range of similar approaches was presented in [13].

2. Methods

By analyzing the available x-ray images it is possible to note that the presence of lung carcinoma in the image is characterized by a different local variance of its gray levels. Then in order to localize and extract the lung nodules we calculate for each pixel of the original image the local variance as illustrated in Fig. 2. So the output image (variance image) is an image with the same size as the original image. Each entry of the variance image is the local variance of the corresponding pixel in the original image.

In the variance matrix we found local maxima by using directional mask maximum algorithm described in [14]. Starting from the locations of these maxima in the original image by using the boundary tracking algorithm presented in [15] we found the contours of the possible nodules in lung tissues (see Fig. 3). However after this segmentation stage we find also many false nodules. Therefore in order to discriminate the true ones we use a probabilistic neural network as classifier.

So that the neural network works properly it's necessary to precisely describe the geometrical properties of nodules lung (features extraction). One of the powerful methods suitable for this task is the momentum method.

Extensive simulations have shown that in the case of 3×3 window size you get the best performance of the proposed methodology in terms of the error rate.

In Fig. 4, we can see that in the left and the right images are shown true nodules while in the middle one is shown a false nodule.

2.1. Feature extraction based on the momentum method

The definition of the moments of the grey value function $I(i, j)$ for the pixels representing objects in x-ray images is

$$m_{p,q} = \sum_{i=1}^{N} \sum_{j=1}^{M} i^p j^p I(i, j). \quad (1)$$