A REVIEW ON COMPUTER AIDED DETECTION AND DIAGNOSIS OF LUNG CANCER NODULES

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ABSTRACT

In this paper, a attempt has been made to summarize some of the information about CAD and CADx for the purpose of early detection and diagnosis of lung cancer. Computer Aided Detection (CADe) and Computer Aided Diagnosis (CADx), are procedures in medical information that assist doctors in the interpretation of medical images. Imaging techniques in X-ray, MRI, and Ultrasound diagnostics yield a great deal of information, which the radiologist has to analyze and evaluate comprehensively in a short time. Thus, the use of digital computers to assist practitioners and physicians in diagnosing diseases and to offer a rapid access to medical information gained importance. CAD systems help scan digital images, e.g. from Computed Tomography (CT), for typical appearances and to highlight conspicuous sections, such as focal areas of lung nodules.

General Terms

Medical Image Processing, Pattern Recognition, Classification

Keywords

Lung cancer, Computer Tomography, Computer Aided diagnosis, Computer Aided Detection

1. INTRODUCTION

Lung cancer is considered to be the main cause of cancer death worldwide, and it is difficult to detect in its early stages because symptoms appear only in the advanced stages causing the mortality rate to be the highest among all other types of cancer. More people die because of lung cancer than any other types of cancer such as breast, colon, and prostate cancers. There is significant evidence indicating that the early detection of lung cancer will decrease mortality rate. The most recent estimates according to the latest statistics provided by world health organization indicates that around 7.6 million deaths worldwide each year because of this type of cancer. Furthermore, mortality from cancer are expected to continue rising, to become around 17 million worldwide in 2030. Early detection of lung cancer is valuable. The 5-year-survival- rate of lung cancer has stagnated in the last 30 years and is now at approximately just 15%. Lung cancer takes more

victims than breast cancer, prostate cancer and colon cancer together. This is due to the asymptomatic growth of this cancer. In the majority of cases it is too late for a successful therapy if the patient develops first symptoms (e.g. chronic croakiness or hemoptysis). But if the lung cancer is detected early (mostly by chance), there is a survival rate at 47% according to the American Cancer Society. But if the lung cancer is detected early (mostly by chance), there is a survival rate at 47% according to the American Cancer Society.

Computer aided diagnosis of lung CT image has been a remarkable and revolutionary step, in the early and premature detection of lung abnormalities. The CAD systems include systems for ‘automatic detection of abnormality nodules’ and ‘3D reconstruction of lung’ systems, which assist the radiologists in their final decisions. Image processing algorithms and techniques are applied on the images to clarify and enhance the image and then to separate the area of interest from the whole image. The separately obtained area is then analyzed for detection of nodules to diagnose the disease [1].

2. CAD SYSTEM ARCHITECTURE

The CAD system is developed for automatic detection of lung cancer through CT. It can provide the valuable information and accuracy of earlier lung nodules detection. It consists of six stages such as (i) preprocessing (ii) enhancement (iii) feature extraction (iv) feature selection (v) classification and (vi) performance analysis. All the stages are compared and studied. To improve the detection rate preprocessing and enhancement techniques are used.

The CADe system comprises image acquisition, preprocessing (like noise removal, artifacts removal such as labels and marks), enhancement (for better view of image for easier interpretation), segmentation denotes the identification of focal areas from CT image.

The CADx sytem acquires the knowledge form CADe and identify whether the lung nodules are malignant or benign. Figure 1a, 1b shows the layout of a CADx and CADe system [2].

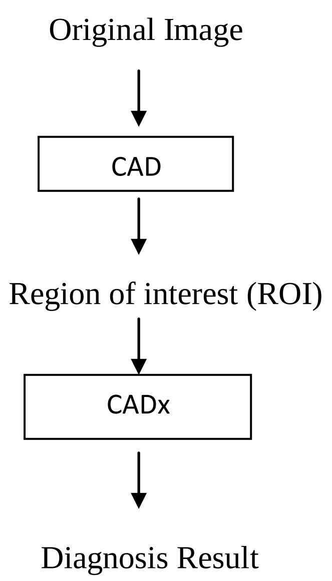

Fig 1a: CADx sytem

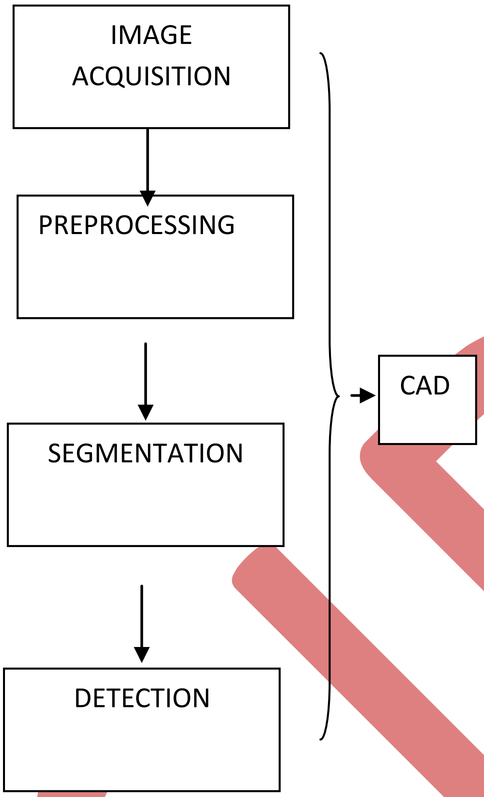

Fig 1b: CADe system

3. DATA BASE (IMAGE ACQUSITION)

The foremost step in medical image processing is image acquisition. This can be obtained from publicly available resources which are shown in table 1. Beyond these databases many research have been carried out by collecting the images from private hospitals and research institution.

Table 1. CT Lung Image Database

Database	Description
ELCAP[21]	Early Lung Cancer Action Program
LIDC[24]	Lung Image Database Consortium

The following figure shows the typical CT image of lung.

Fig 2: Typical CT image of lung

4. PREPROCESSING

Preprocessing is a vital step that is used mainly to reduce the noise artifacts in the image, boundary identification. It can be used for improving the image quality by eliminating the regions which reduce the accuracy. These techniques are used for noise elimination and lung area identification. These two techniques are worked out simultaneously [4] [5]. Table 1 shows an overview of different preprocessing methods.

Table 1. An overview of different preprocessing methods

Methods	Remarks
Anisotropic diffusion filter [46] [57]	The image gets smoothes to different extreme in the direction of the intensity gradient.
Wavelet filter [58]	Certain noise-like components are preserved for identification of Region of Interest(ROI).
Gabor function[22]	Local and multi-scale decomposition
3D dot-enhancement filter[3]	voxel-based neural approach (VBNA)
Pixel thresholding[7]	Different lighting conditions are handled
Gaussian or averaging filter[41]	Remove grain noise
Quasi-gabor filters [43]	Removal of overlapped ribs and and clavicles with nodules
Emphasis filters[59]	To identify the spherical objects
Multiple Thresholding[61]	To remove noise in CT image.
Laplander of Gaussian filter[62]	The streak shadow is removed.
Selective enhancement filter[64]	Blob structure has been enhanced
Ring average Filter[63]	Identify and removal of nodule like structure.
Spherical enhancement filter[65]	Blob structure has been enhanced
Nodule filtering and unsharp masking[66]	Blob structure has been enhanced
Combined cylindrical and spherical filter[67]	Nodule structure has been enhanced and the vessels are suppressed
Morphological filter[68][12]	For image enhancement
Cylindrical filter[69]	\The vessel like structure are not considered
Median filter[70]	Reduction of noise
Anatomy based segmentation[71]	To emphasis nodule boundary

Probabilistic atlas based[75]	To limit the search area of the blob detectors

5. SEGMENTATION

Segmentation of an image entails the division or separation of the image into regions of similar attribute. The ultimate aim in a large number of image processing applications is to extract important features from the image data, from which a description, interpretation, or understanding of the scene can be provided by the machine. It is the process of differentiating different structures in the image, e.g. heart, lung, ribcage, possible round lesions and matching with anatomic databank. Several techniques like boundary extraction, region growing, gray-level histogram thresholding, deformable models (snakes - active contour maps), level set methods, can be used. The segmentation of medical images is challenging because a ground truth is often not available. Computer-Aided Detection (CAD) systems are dependent on ground truth as a means of comparison; however, in many cases the ground truth is derived from only experts' opinions. When the experts disagree, it becomes impossible to discern one ground truth [30]. Segmentation algorithms operate on the intensity or texture variations of the image using techniques that include thresholding, region growing, deformable templates, and pattern recognition techniques such as neural networks and fuzzy clustering [55]. The most frequently used techniques for segmentation are statistical methods, geometrical, structural, model based, signal processing methods, spatial domain filters, Fourier domain filtering, Gabor and wavelet models have also been used in most works present in the literature[35][36]. A novel approach of local density maximum algorithm was carried out to detect small nodules [42]. Discriminate functions based on Mahalanobis distance have been used on the suspicious shadows to determine normal or abnormal [40]. Table 2 shows various segmentation methods.

Table 2. An overview of segmentation methods

Method	Remark
Rolling ball Algorithm[13]	Loss of juxapleural nodule are overcomed
TRACE method[14]	Non-approximation technique for edge detection
Knowledge based segmentation [15]	Uses active contour model.
Rule based Region growing [19]	Similarity Index is caluculated by Elastic registration of inclusive scans using mutual information
Hybrid Segmentation [25]	Used inverse region growing seed for the separation of lungs and airways.
Cellular neural network(CNN)[29]	artificial bee colony algorithm used for segmentation
Pixel Thresholding[37]	Lung high resolution CT(HRCT) images are segmented accurately
Genetic cellular neural networks, Fuzzy rule based thresholding[38]	To achieve the accurate ROIs
Template-matching[39]	It introduced genetic algorithms(GA) template matching(GATM) technique for detecting nodules resides within the lung area
Multiscale joint segmentation[33]	It extends the robust mean shift-based analysis to the linear scale-space theory
Iterative gray level thresholding[17]	Extraction thorax and lungs from the CT Scan images
Optimal gray-level thresholding[16][18]	Identifies the interior region of thorax area
Fuzzy thresholding[21]	Detecting both solid nodules and ground-glass opacity (GGO) nodules
Region growing[26]	3D geometric features is applied to detect nodules after the extraction of pulmonary parenchyma
Wavelet Theory[47]	The non-spherical shaped nodules are detected by using Anti-geometric diffusion and Rule-based techniques
3D Template Matching[34]	To find the structures with homogeneous properties of nodules
Local Binary Pattern[44] [45]	Converting 2D to 3D LBP to achieve good performance
Marker-based Watershed Transform[72][73]	Reduces the regional minima and couple them within the regions of interest to suppress over-segmentation
Gray level thresholding[10][17]	To identify initial lung nodule candidates, by computing morphological and gray-level features
Fuzzy C-means [74]	To identify the focal areas of lung nodules.

6. CLASSIFICATION

After the structure is analyzed, each and every region identified is evaluated individually (scoring) for the probability of a True Positive (TP). Several methods exists for the classification process. Some of them are, rule based methods, minimum distance classifier, cascade classifier, Bayesian classifier, Multilayer perception, Radial Basis Function network (RBF), Support Vector Machine (SVM), Artificial Neural Networks, Fuzzy logic etc.

Several techniques can be used as classifiers in the final stage of nodule detection: based on either rules based classifier[60] or linear classifiers [39], by combining models (template matching) [49],analysis of the nearest cluster [50,51], support vector machine [48], neural networks [20,30,52,59] and Bayesian classifier [5,53]. The features included for classification are based on voxels density, shape analysis, spatial characteristic and the information of size.

Table 3 shows the different classification techniques. Figure 3 shows the examples for Benign and malignant lung nodules after classification [77].

Table 3. An overview of classification techniques

Method	Remarks
Rule Based Classification[76]	To separate nodules and non-nodule structure.
Artificial neural network ensemble[6]	To improve the accuracy of false negative identification
Neural Network[32][56]	Observed the lesions <3mm
Linear Discriminative Analysis[27]	The false positive rate is 1.74/slice
Hopfield Neural Network (HNN)[28][31]	It requires minimal time for detection
Massive Training Artificial Neural Networks (MTANN)[20]	It uses non-linear filter to train the chest radiographs for better performance
Fisher linear discriminant (FLD) classifier [78]	Generates small number of True Positive training samples
Support Vector Machine(SVM)[79]	To reduce the false positive rates
Fuzzy rule based[23]	It generates rule based on symptoms

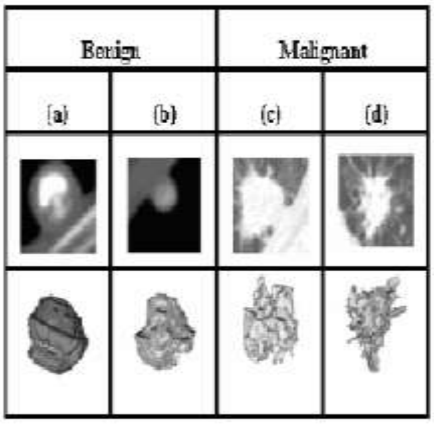

Fig 3: Examples for Benign and malignant lung nodules

7. PERFORMANCE EVALUATION

The evaluation of a diagnosis system depends on statistical decision theory and gives estimates of the probabilities of decision outcomes of the various kinds of decision criteria used by the system. True positive fraction, false-positive fraction, sensitivity, specificity and Receiver Operator Characteristics (ROC) [54] are some performance measures used to evaluate a CAD system. A true positive is an abnormality classified as malignant when it is actually malignant. A true negative is an abnormality classified as benign when it is actually benign. Sensitivity is the ratio between true positives and total positives. Specificity is the ratio between true negatives and total negatives. Receiver Operator Characteristic (ROC) is an analytical procedure whose curve shows a relationship between the true positive probability and the false-positive probability. ROC provides a desirable index of accuracy and the appropriate basis for an index of efficacy.

Confusion matrix was used to calculate the performance of the classifier. Table 1 shows the confusion matrix. It is a specific table that helps to visualize the performance of a learning algorithm. Each column of the matrix represents the predicted class, and each row represents the actual class.

Table 4. Diagnosis Result

Diagnosis	Abnormal condition of patient	Normal condition of patient
Abnormal	True positives	False positives
Normal	False negatives	True negatives

In this diagnosis result, if the diagnosis is abnormal and the patient is also abnormal then it is called as TP, if the diagnosis is abnormal and the patient is normal then it is called as FP, if the diagnosis is normal and the patient is abnormal then it is called as FN and if the diagnosis is normal and the patient is also normal then it is called as TN .

Sensitivity = True Positives / (True Positives + False Negatives)……………………………… ..(1)

Specificity = True Negative / (True Negatives + False Positives)……………………………….. (2)

8. SOFTWARE

ImageChecker CT (R2 Technologies, Sunnyvale, Calif) and Nodule Enhanced Viewing (NEV) (Siemens Medical Solutions, Forchheim, Germany) in which sensitivity was 73% with ImageChecker CT and 75% with NEV[8]

IMS2 is an Integrated Medical Software system for the analysis of Ion Mobility Spectrometry (IMS) data [11] produces 99% classification result.

Magic 5[9] uses distributed computing infrastructure (GRID) to increase computational speed and accessibility, and share distributed image databases and aims at diagnosing early detection of lung cancer.

9. CONCLUSION

CAD produces a result as a "second opinion" in order to assist radiologists in the diagnosis of various diseases on medical images. Combining CAD and applied mathematics various research have been made to produce the diagnosis process. The advantages of CAD for assisting radiologists in detection of lung cancer has been demonstrated by a number of prospective clinical trials in recent years and the development of CAD in other areas is also being actively pursued by researchers. The vast amount of research related to analysis of lung cancerous nodules, as well as widespread interest from the medical community stimulates the development of commercial CAD and CADx systems. In this paper a survey have been studied and compared on various research work in preprocessing, segmentation, classification in detecting lung nodules. The future research direction is to develop some new techniques for diagnosing the tumor and to provide a better framework for development of CAD system and to increase the survivability of the human race.

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