AN OVERVIEW OF CAD SYSTEMS FOR LUNG CANCER DETECTION

[1]Shilpa Unnikrishnan M.K., [1]Shamya C, [2]Neenu P.A.

[1]PG Scholar, [2]Assistant Professor, Dept. of ECE, Thejus Engineering College,Thrissur

shilpaunnimk@gmail.com

Abstract— Lung cancer is one of the acute types of cancers with the least survival rate. Manual evaluation of the lung CT scan is an exhaustive task. Thus the use of computerized systems can provide the assistance to the expert practitioners in the comprehensive assessment of the medical information. Lung CAD system focuses on the detection of the potential abnormalities namely nodules which can either be malignant or benign. This paper reviews the techniques involved in CAD systems in biomedical image processing domain that offer the detection of the abnormal growth of cells in the lungs.

Keywords— CAD, Classification, False positives, Lung nodules, Region growing, Segmentation, Thresholding

INTRODUCTION

Lung cancer is regarded as one of the most dangerous diseases which pose threat to the existence of mankind. In spite of moderate improvements in the treatments of the lung cancer, the prognosis is however inferior as the survival rate after the diagnosis is depreciating even with the development of several equipments [19]. The survival of lung cancer is closely related to the stage at the time of diagnosis. The root cause of this deadly disease is the tobacco smoking. It is highly difficult to detect the presence of malignancy as it does not exhibit noticeable symptoms. Various Computer Aided Detection (CAD) systems have been developed as a second opinion to the diagnostic interpretation of the physician. The establishment of the Computed Tomography (CT) imaging modality paved the way for the detection of tumours inside the pulmonary structures. The lung CT images depict the abnormalities in lungs with better clarity, low distortion and a minimum amount of noise.

CAD system is regarded as an inevitable tool in medical radiology which aims at improving the performance of radiologists providing high sensitivity in the efficient diagnosis of the various diseases. Pulmonary CAD system[1] has been a phenomenal and revolutionary step, in the early and premature detection of lung abnormalities. The systems make use of the CT scan images to determine the pathologic condition of the patient by extracting the features of the potential abnormalities. Computerized detection helps to revaluate the diagnostic decision if necessary. The CAD systems include systems for automatic detection of nodules and 3D reconstruction of lung systems, which assist the radiologists in their final decisions. Various image processing techniques are applied on the medical images to enhance the image and to use for the further clarification of diagnosis.

The paper is arranged in the following way: The section Overview of Computer Aided Detection Systems presents a brief description of CAD systems and the following section depicts the CAD Systems for lung cancer detection in detail which includes the architecture review of CAD systems for lung cancer detection and the various techniques involved in each stage.

OVERVIEW OF COMPUTER AIDED DETECTION SYSTEMS

Computer Aided Detection (CAD) is a proven clinical tool that assists the physicians for the detection of deadly diseases. These systems provide a second opinion in the interpretation of the diagnostic results. CAD refers to pattern recognition software that identifies suspicious features on the image and attracts the attention of the radiologist, in order to reduce false negative readings. The Radiologist reviews the examination and then activates the CAD system and performs the revaluation of the results before issuing the final diagnostic results. CAD has its enormous impact in the medical industry as it provides the clinical interpretation in the detection of the deadly diseases. CAD techniques attract the attention from the in different fields. The main research task in the development of CAD systems is to improve the performance for widely applying the system in medical field.

The performance of a computer-aided cancer detection and diagnosis system needs integration of many independent and self-contained systems to achieve the best performance. The in-depth knowledge of the subsystems including the feature extraction and classification systems are required to attain the improved performance of the whole system. Even though CAD systems are proven to improve the efficiency of radiologists in the detection of nodules, they are not widely used in clinical practice. As a result, CAD systems have become one of the most prominent areas of research in medical image processing.

The practice of radiology comprises of the visual perspective of an image and the interpretation or cognition. Manual strategies such as double reading can be adopted but as it is an exhaustive task, computerized systems have been developed. To provide workflow efficiency, the potential of CAD system with associated tools is highly accepted. CAD algorithms are developed to find out the same features that a Radiologist looks for during case review. But a further investigation is demanded as it may lead to some perception error and from there to wrong diagnostic interpretation. The CAD algorithms require a digital data set of the image for analysis. The medical images are usually in Digital Imaging and Communications in Medicine (DICOM) format compatible with the open source software.

CAD SYSTEMS FOR LUNG CANCER DETECTION

A well-developed computerized system for the detection and extraction of abnormalities provides the assistance to experts regarding the classification of image features into normal and abnormal categories. The use of digital computers in the detection of lung nodules in pulmonary CT images was first reported by in the early 60s [4]. The lung nodule detection system was established only after twenty years. Due to the lack of computational resources and advanced image processing techniques the first results were not so interesting. Current researches, however, have been showing that the accuracy of diagnosis with the advancing techniques in the biomedical image processing. The parameters including the speed, sensitivity and reduction of false positives were improved in the late 90s. Thresholding was used for nodule selection and Artificial Neural Networks for elimination of false positives. The main problem encountered was the low level of automation of systems because scanners were used for X-ray films, which is usually a manual process.

I. Lung Cancer and Lung Nodules

Lung cancer is treated as a worldwide predicament and is a major reason behind the cancer-related deaths in humans around the globe. It is one of the most deadly cancers with the least survival rate after diagnosis. Survival from lung cancer is directly related to its growth at its detection time. The earlier the detection is, the higher the chances of successful treatment are. Lung cancer is caused by uncontrollable irregular growth of cells in lung tissue which proliferate in an uncontrolled way [18]. It occurs after repeated inserts to the genetic material of the cell. Early detection of lung tissue abnormalities can help lung patients getting early treatment for their illness. Lung cancer often has no symptoms until it has metastasized due to the limited number of pain receptors in the lungs. The most frequently used imaging technique in the lung cancer diagnosis is Computed Tomography. Early detection of lung cancer, which is typically viewed in the form of pulmonary nodules, is an efficient way of improving the survival rate.

Lung nodules are the potential abnormalities that are roughly spherical with round opacity and a having a diameter of upto approximately 30mm. Based on their relative positions, the nodules are classified into well-circumscribed, vascularized, juxta-pleural and pleural-tail[3]. This classification is very significant since the intra-parenchymal nodules are having high probability of malignancy. Well-circumscribed nodule is located centrally in the lung without any connections to vasculature. Vascularized nodules are connected to the vessels even though it is located centrally in the lung. The name of pleural-tail nodule is due to a portion of the nodule being connected to the pleural surface by a thin tail. Juxta-pleural nodule has a large portion connected to the pleural surface. This is a straightforward classification technique to label a nodule by analysing its position and connections which can be supportive in the detection of the lung cancer. CT scan images depict the pulmonary abnormalities in a more accurate way. A nodule is defined as a rounded and irregular opaque figure on a CT scan. Fig 1 shows transaxial CT images of the four types of lung nodules namely well-circumscribed, vascularized, juxta-pleural and pleural tail nodules shown from left to right.

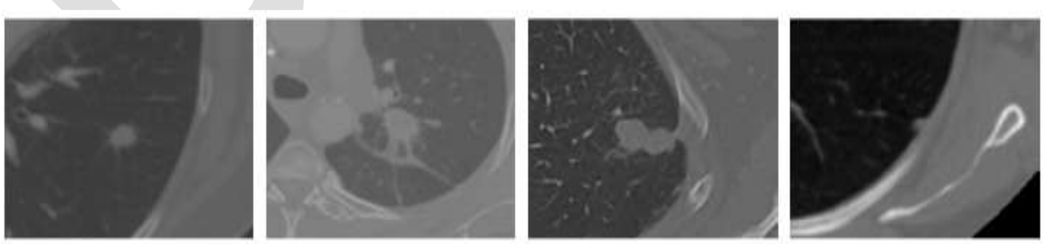

Fig 1: Transaxial CT images[1]

II. Architecture Review of Lung Cancer CAD systems

CAD systems for detecting pulmonary nodules are usually composed of five subsystems namely acquisition, preprocessing, segmentation, nodule detection and elimination of false positives [3].

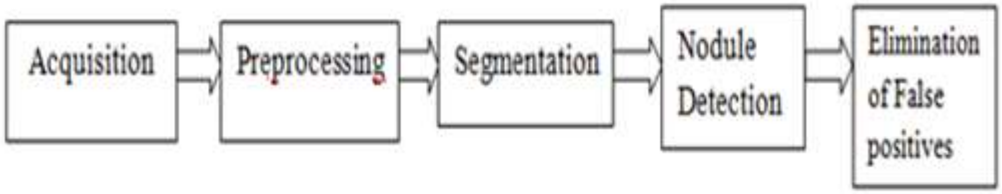

Fig 2. CAD system Architecture [4]

The CAD system architecture is shown in Fig 2. Acquisition of images involves obtaining the CT scan image from either public or private database. Preprocessing stage includes the resizing of the images, image enhancement, noise removal, extraction of ROI and segmentation of the nodule. The main objective of nodule segmentation is to accurately define the region of measurement from where the best information using an adequate set of features can be obtained. The thresholding approach in segmentation involves application of a threshold of intensity to perform the separation as the darker shades in CT scans represent the lung tissues when compared to other organs. Nodule detection aims at the determining the pulmonary nodules in the image.

The main issue that persists in the CAD systems is to discriminate true nodules from other pulmonary structures. The main relevance of pulmonary nodules is that they often represent the initial radiographic findings of lung cancer. The best method to segment the tumour regions is the Region growing method because the borders are thin and connected each other. Initially, the possible nodules detected are segmented and their features are extracted. The main extracted features are intensity values of pixels, morphology and texture. After the identification and characterization of nodules, the CAD system tries to eliminate false positives. In order to eliminate FP, classifiers are used. A classification system generally consists of training and testing phases. The classifier is trained to learn the parameters of the system in the first phase and the testing phase is to evaluate the success of the classifier. The commonly used classifiers are Support Vector Machines, Artificial Neural Networks etc.

1. Image Acquisition

CT scan images for the Lung CAD systems are obtained from the public databases[5] namely, Early Lung Cancer Action Program (ELCAP), Lung Image Database Consortium (LIDC) in national imaging archive and Medical Image Database. Beyond the public lung image database private database obtained from the hospitals are also used. Image quality in CT scanning is affected by various parameters namely radiation dose, slice thickness, detector efficiency etc. The low dose CT scan is used for reducing the exposure to the radiation by trading off the image quality.

2. Preprocessing

Preprocessing in the Lung CAD system refers to the steps necessary to enhance the image quality by eliminating the artifacts due to noise which can improve the visibility of the extracted pulmonary nodule. This stage removes defects caused by the image acquisition process. Types of filters used in preprocessing[13] stage are Laplacian of Gaussian filter, Ring Average filters, Median filters, Morphological filters, Selective Enhancement Filter etc. The LoG filter enhances the blob like structures with respect to the variation in intensity. Takahiro et al. [17] proposed a selective enhancement filters for the enhancement of blob like structures and for suppressing the vessel like structures.

For the extraction of lungs two techniques are suggested namely rule-based reasoning and pixel classification [6]. Pixel classification includes sequence of steps, tests, and rules. These include techniques like Local Thresholding, Region Growing, Edge Detection, and Morphological operations. In pixel classification, each pixel from the image is classified into an anatomical class. A rule-based thresholding technique is implemented by Naveed Ejaz et.al [6]. A threshold based on the density histogram was selected and the lung mask is obtained so as to separate the lung parenchyma from the other anatomic structures on the CT scan images. Disha et.al [7] proposed image slicing algorithm for the extraction of lung region. To enhance the quality of image various morphological operations like opening, closing followed by erosion, dilation were applied to remove any irrelevant information in the image.

3. Segmentation

The lung CT image needs the segmentation of the anatomical structures including lungs, lung lobes, airways, vessels etc. Due to the similar densities of the pulmonary structures and the behaviour of the scanners used, segmentation is considered to be a complex task. Several techniques have discussed .the segmentation activity. Based on the accuracy, processing time and level of automation, the segmentation procedures are evaluated The main techniques in segmentation of lung regions are thresholding approach, segmentation by deformable models, shape and edge based approaches[3],[13].

In the segmentation approach based on thresholding, a threshold of intensity to perform the separation is utilized. This approach can be performed iteratively or used in combination with Otsu's thresholding, morphological operations, edge detection algorithms [7] etc. Gao et.al [14] proposed an accurate segmentation method with four steps namely the extraction of the airway from lung region, removal of pulmonary arterial and venous vessel trees by finding a suitable threshold, application of a large threshold to separate right and left lung and morphological smoothing of lung boundary. The accuracy of the thresholding approach lies mainly upon image acquisition protocol and acquisition type. The main issue behind this type of technique is that its accuracy is deteriorated by the type of equipment that makes the acquisition and the location of nodules.

Deformable models are curves or surfaces, for image segmentation, which deform themselves according to the influence of internal and external forces The main types of deformable models used for segmentation of lung images are active contours and level set based deformable models[8]. The deformable model started from an initial segmentation obtained by a threshold estimated from CT data. The major drawbacks of this segmentation are its initialization process, speed issue and the inability of external forces to capture the lack of homogeneity in regions of the lung.

The extensive use of edge detector filters and wavelet transforms comprises of the edge based segmentation algorithms. The first derivative Guassian filters are used to point out an outline of lung borders in [15]. Laplacian of Gaussian (LoG) operator was used to find a continuous lung contour which was combined together to extract the final lung region. Edge point detection method using spatial edge detection filters with closed contour for lung boundaries was proposed.

4. Nodule Detection

Lung nodules detection aims at determining location of lung nodules. Accuracy of lung nodule segmentation and the method for false positive reduction are the main parameters which affects the detection performance [5]. Isolated solid nodules are easy to detect as the contrast between tissue and air is clearly visible. But if the nodules are pleural-attached or vascularized, the detection becomes difficult. Nodule segmentation is crucial for the diagnostic and treatment procedures for monitoring the tumour growth in the lung. The main techniques used for the candidate nodule detection are thresholding, morphological processing, template matching, adaptive thresholding, region growing method etc.

Armato et al. [9] applied multiple gray-level thresholds to the volumetric lung regions to identify nodule candidates. It analyses the complete lung with a grayscale threshold method and searches for voxel in the lung. If the grayscale of a voxel is between the threshold, the voxel is marked by the algorithm and a 3D region growing with an eight neighbour relation is started. The first relation is done with a low threshold followed by the one with the high threshold. These regions are marked for further processing and analysis. Template matching methods [13] are used to segment the solitary pulmonary nodules. With this approach, circular or semicircular nodules can be identified. To identify the nodules situating inside and on the boundaries of lung area, Assefa et.al [16] developed both circular and semicircular templates. The structure of the lesion is irregular as they are connected to the vasculature or pleural region. In the Region growing method [11] regions are constructed and the region grows from this seed by comparing the neighbouring voxel values based on some user criterion such as pixel intensity. The disadvantage of this approach is that nodule detection is semi-automated. Contextual clustering has been combined with region growing for reducing the segmentation steps in [13]. It outperformed the conventional algorithms by providing high accuracy.

5. Elimination of False Positives

False Positives (FP) are the non-nodule structures detected as nodules. The known CT artifacts which are caused by breathing or the heart beat, or partial volume effect also increase the FPs. False positives are to be eliminated for the better accuracy of the CAD system. The increase in the number of false positives is contributed by the attached vessels and airways[5]. Thus the reduction of false positives must be performed correctly to identify the pulmonary nodule. Each and every region is individually analysed for finding the true positive nodule candidate.

Classifiers are used for evaluation of the nodules. Feature extraction is a important step in the system which involves the extraction of information about size, shape, texture and intensity values. Classification is mainly composed of training phase and testing phase. Training phase includes the supervised training and validation process. In testing phase, the lung CT scan images are compared with the extracted features in the reference model. Khin Mya Mya Tun [12] proposes a CAD system with Artificial Neural Network as the classifier. In classification, feed-forward neural network is used to classify the lung cancer stages. This system can know the condition of lung cancer at early stages, so it can play a very important and essential role to avoid serious stages. Rule Based Classification [13] can be used to separate nodules and non-nodule structure. Suzuki et.al [14] proposes a multiple massive-training Artificial Neural Network to reduce the number of false-positive results. An MTANN is a highly nonlinear filter which uses input images and corresponding teaching images for training. To reduce background level effects in chest radiographs, a background-trend-correction technique, followed by contrast normalization, is applied to the input images for the MTANN. Multi MTANN provided acceptable level of sensitivity with reduction of false positives.

CONCLUSION

In this paper, an overview of CAD systems for lung cancer detection has been discussed. With the least survival rate, lung cancer is proved to be one of the most dangerous catastrophic threats among the cancer related fatalities. Automation introduced in the detection of the cancer laid the foundation for the improved medical assistance. The generic CAD system architecture is designed in such a way so as to obtain a considerable amount of accuracy and sensitivity with minimum number of false positives. Various methods for the computerized detection techniques have been examined. Collaborative efforts are required for the wide establishment of computer aided detection systems in medical sector for the prognosis of the lung cancer and its related ailments.

REFERENCES:

[1] Gonçalves., "Automatic Lung Nodule Classification in Chest Computerized Tomography Images"., International Conference on Machine Vision Applications,2015.
[2] S.Shaik Parveen, Dr.C.Kavitha., "A Review on Computer Aided Detection and Diagnosis of Lung Cancer Nodules"., International Journal of Computers & Technology Volume 3 No. 3, Nov-Dec, 2012.
[3] Macedo Firmino et.al.," Computer-aided detection system for lung cancer in computed tomography scans: Review and future prospects"., BioMedical Engineering OnLine 2014.
[4] Rakesh Kumar Khare, G. R. Sinha, Sushil Kumar.,"CAD for Lung Cancer Detection: A Review"., IJMTER 2015
[5] Ashish kumar dhara et.al., "Computer-aided Detection and Analysis of Pulmonary Nodule from CT Images: A Survey., IETE Technical Review, 29:4, 265-275
[6] Naveed Ejaz et.al.," Implementation of Computer Aided Diagnosis System for Lung Cancer Detection"., Lecture Notes on Software Engineering, Vol. 1, No. 4, November 2013.
[7] Disha Sharma, Gagandeep Jindal., "Identifying Lung Cancer Using Image Processing Techniques".,ICCTAI 2011.
[8] Bin Chen.,"Automated Segmentation of Lung Nodules and Pulmonary Blood Vessels and Follow-up Analysis of Lung Nodules from 3D CT Images"
[9] Armato SG et.,al., "Computerized detection of pulmonary nodules on CT scans"., Radiographics 1999, 19(5):1303–11.
[10] A.Prabin, DR. J.Veerappan., "Automatic Segmentation Of Lung Ct Images By Cc Based Region Growing".,Journal of Theoretical and Applied Information Technology October 2014. Vol. 68 No.1.
[11] Khin Mya Mya Tun.,"Feature Extraction and Classification of Lung Cancer Nodule using Image Processing Techniques"., International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181
[12] Cambron N. Carter., "CAD system for lung nodule analysis"., Thesis and dissertations, University of Louiseville.
[13] Bhavanishankar .K and Dr. M.V.Sudhamani.," Techniques for Detection of Solitary Pulmonary Nodules in Human Lung and their classifications -A Survey"., International Journal on Cybernetics & Informatics (IJCI) Vol. 4, No. 1, February 2015.
[14] Q. Gao, S.Wang, D. Zhao, and J. Liu, "Accurate lung segmentation for X-ray CT images", in Proceedings of the 3rd International Conference on Natural Computation (ICNC '07), vol. 2, pp. 275– 279, 2007.
[15] P. Campadelli, E. Casiraghi, and D. Artioli, "A fully automated method for lung nodule detection from postero-anterior chest radiographs", IEEE Transactions on Medical Imaging, vol. 25, no. 12, pp. 1588–1603, 2006.
[16] Mickias Assefa et al., "Lung nodule Detection Using Multi Resolution Analysis", proc. IEEE, International Conference on Complex Medical Engineering, ICME, pp.457-461, 2013.
[17] Takahiro Miyajima et al., "Classification of Lung Nodules Temporal Subtraction Image Based on Statistical Features and Improvement of Segmentation Accuracy", proc. 12th IEEE International Conference on Control, Automation and Systems, Jeju Island, Korea, pp.1814-1817, 2012.
[18] M.V. Sprindzuk et al. "Lung cancer differential diagnosis based on the computer assisted radiology: The state of the art", Polish journal of Radiology, Pol J Radiol, 75(1): 67-80, 2010.
[19] World health organization Cancer: www.who.int/gho/ncd/mortality_morbidity/cancer/en