Implementing Computer Aided Diagnosis with PACS

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***Abstract*-Computer Aided Detection (CADe) or Computer Aided Diagnosis (CADx) are applied in radiology to assist doctors in the interpretation of medical images. Computer Aided Diagnosis combines Artificial intelligence and Digital Image Processing with radiological image processing. A typical application where Computer Aided Diagnosis is used nowadays is in the field of Mammography.**

Computer Aided Diagnosis is purely based on algorithms. It has become a useful tool for doctors in areas such as radiology, CT, MRI or diagnostic ultra sound. Computer Aided Diagnosis systems are now being implemented as a part of Picture Archiving and Communication System (PACS) as a package. This helps the physicians and radiologists to compare the past and present medical images of a patient with a huge amount of database and arrive and a better and accurate decision in a short time span. Quantification is often the main aim of radiological examinations. Once the diagnosis has been made the physicians need to determine the extent and progression of disease.

The main aim of this article is to communicate the concept of Computer Aided Diagnosis, current areas of adapting CAD systems into various medical images, the benefits of in cooperating CAD with PACS and new developments in CAD technology.

I. INTRODUCTION

Medical Computer science or health informatics which can also be called as medical information science is the science of using system analytical tools to develop procedures (algorithms) for process control, decision making and scientific analysis of medical knowledge. Medical Image Processing and Medical Image Analysis are the two main areas where CAD (Computer Aided Diagnosis) can be applied to help the physicians. Medical Image Processing deals with the development of scientific approaches for the selective visualization of data for further analysis. Medical Image Analysis concentrates on the development of techniques to supplement the qualitative assessment of medical images by human experts. It provides variety of information that is quantitative objective and reproducible.

CAD is diagnosis made by radiologist by incorporating the output of computerized image analysis methods into his or her decision making process. Though CAD is defined as a study confined to marking problematic structures and sectors, it may be interpreted broadly to incorporate both in the detection of abnormality and the classification task(likelihood that the abnormally represents a malignancy).It is an interdisciplinary technology combining some elemental parts of artificial intelligence and digital image processing with radiological image processing .Nowadays CAD is being used in the areas like detection of tumor , preventive medical checkups in mammography (breast cancer) detection of polyps in the colon and the lung cancer. CAST (Computer Aided Simple Triage) is another type of CAD.CAST is applied in a life threatening situation to categorize the patient, so that he/she may be guided to the adequate and proper levels of physicians. At the resent stage CAD cannot be considered as a substitute for doctors, but it can give an active supporting role to the physicians for arriving at a better conclusion or judgment.

II. HISTORY AND EVOLUTION OF CAD

The amount of images acquired during a CT (Computed tomography) scan is becoming overwhelming for human vision and the abundance of image data may lead to false conclusion due to oversight errors. On behalf of the researches and studies conducted in this field, it was found that history of CAD began in 1955(not commercialized) when the radiologist Dr.Lee Lusted mentioned the help of computers in medical imaging. Lee Lusted mentioned the potential use of digital computers for large-scale data problems in medicine. The first study on CADe of abnormalities in mammograms was published by Winsberg in 1967[5].In 1973 Toriwaki et al reported the first study on CADe of a focal abnormality in the chest radiographs. In the mid 1980’s researchers in the Kurt Rossmann laboratories in the department of Radiology at the University of Chicago began studies on the development and evaluation of CAD. In 1988, a venture company R2 technology (now Hologic) which obtained University Of Chicago, received approval for the first commercial CAD system for mammography from the US Food and Drug Administration (FDA).

III.STAGES IN CAD ARCHITECTURE

CAD can be divided into 2 sections. CADe(Computer Aided Detection) and CADx(Computer Aided Diagnosis).The structure or architecture of a CAD system is as shown below.

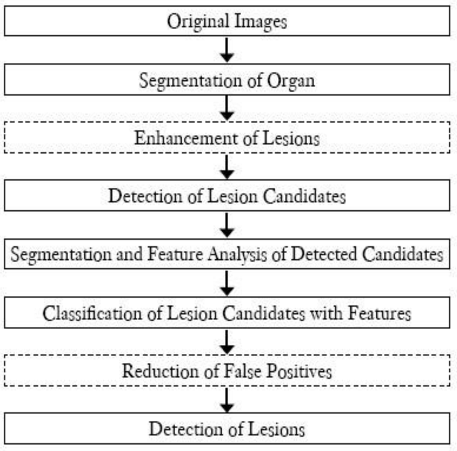

Fig 3.1 CAD architecture

The first stage in CAD system is the preprocessing stage. This stage mainly focuses on the reduction of noise (errors) in the image and leveling the image. Methods of noise reduction like msn filters, median filters, Laplacian filers, Gaussian filter etc are applied in the preprocessing stage. Image harmonization is obtained by enhancing the edges of the image and enhancing image contrast. Enhancing the edges is made possible by unsharpening and wavelet transforms. Histogram equalization is the tool that is widely used for enhancing image contrast.

After preprocessing the image the next part is to segment the image. Segmentation of different parts like lung, heart etc is done for better analysis. Segmentation aims at making the rest of the steps focus on the organ.

Next stage after segmentation is to mark the ROI (Region of Interest). The area where the study should be focused is identified .After that ROI region is evaluated and classified individually. Methods like Nearest Neighbor Rule (in mammography), semiautomatic methods like seeded region growing are applied in ROI for better evaluation and classification. The success of CAD depends upon two factors specificity and sensitivity. Sensitivity is the true positive rate (TPR) and specificity is the true negative rate (TNR).

Truth table for detecting a disease and a non disease using FP and TP

	Disease	Non Disease
Test Positive	TP	FP
Test Negative	FN	TN
Total	TP+FN	FP+TN

In the above truth table TP stands for true positive,FP False positive,FN False Negative and TN true negative. A correct hit is marked as true positive and an incorrect hit as False Positive.

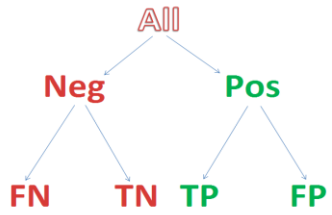

Fig 3.2 Classification of FP and TP

Sensitivity to the disease is the percentage of all disease cases that are ranked by the decision support as positive. TPR=TP/(TP+FN).Though sensitivity is necessary for the success of CAD system, it alone is not sufficient. We want to avoid the labeling of non disease as disease. That is often measured by specificity. It is the percentage of those without disease who are correctly identified as not having disease. (TNR=TN/FP+TN).In some cases we specify the complement to specificity that is the anti sensitivity as the False Positive Rate (FPR) . FPR=FP/(FP+TN)=1-TNR.The figure given below is an example for plotting sensitivity and specificity.

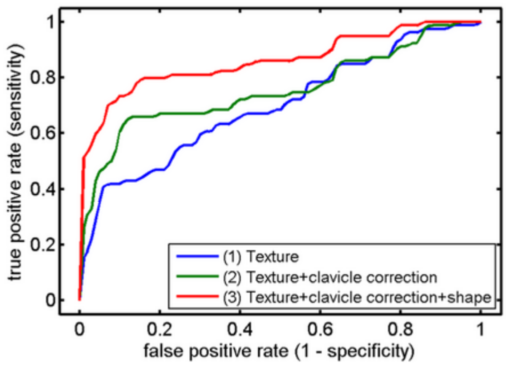

Fig 3.3 Sensitivity and Specificity

In addition to this some CAD systems also plot an ROC (Receiver Operator Curve) which is a plot of sensitivity versus ant sensitivity for different diagnostic thresholds of a test. Below given figure is an example of plotting ROC.

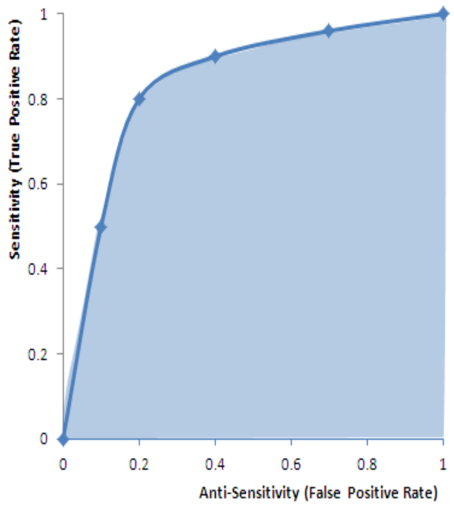

Fig 3.4 ROC (Receiver Operator Curve)

The main objective of a CAD system is to reduce as many FP's as possible. This increase the hit rate or sensitivity of CAD system. By reducing FP's and correctly marking TP's the non lesion areas can be removed and a clear boundary for the lesion area can be marked. Feature based machine learning techniques (classifier) is applied at this stage to mark the optimal boundaries. Algorithms like Linear Discriminent Analysis (LDA), Quadratic Discriminent Analysis (QDA), Multi layer Perceptron (Artificial Neural Networks model), Support Vector Machines (SVM) are applied at this stage.

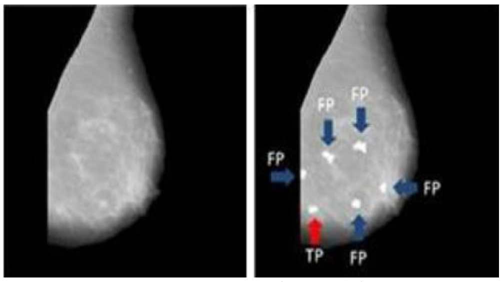

Figure 3.5 illustrating marking of FP's and TP's

As computational power increased new methods like pixel/voxel based machine learning techniques are being used. This method uses the pixel/voxel values in the image directly for evaluation and classification. This leads to better accuracy of the results. After defining ROI gray level feature, texture feature and morphologic feature are extracted from the image.

To improve the performance of CAD systems researchers sometimes employ an additional step, that is enhancement of lesions, after the segmentation of ROI.This aims at improving the sensitivity for detection of lesion candidates in the proceeding steps.

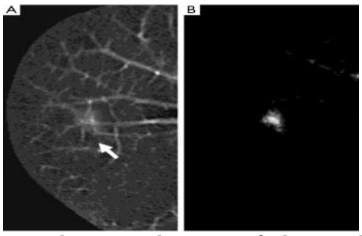

Fig:3.6 Lesion enhancement by means of a lesion enhancement filter.

The evaluation of the developed scheme is the last step in CADe. The success of CAD depends upon how efficiently the radiologists use the CAD output for evaluation. As mentioned CADe is the first stage that involves detection, Diagnosis comes under the CADx scheme. The flowchart for a generic CADx is as shown below.

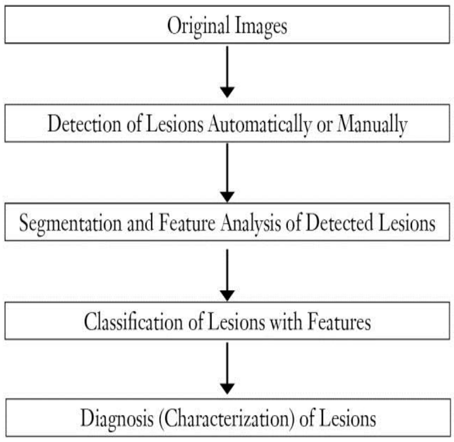

Fig: 3.6 CADx Architecture

CADx scheme starts from detected lesion, otherwise we can say that CADx starts from the location of a lesion of interest.CADx scheme include distinction between benign and malignant status of detected lesions. By examining the extracted features, lesions can be classified as malignant or benign or nearly malignant or nearly benign.

IV. APPLICATIONS OF CAD

CAD in mammography:

Breast cancer has become one of the most deadly diseases for women today. But it has been found that early detection leads to better survival rates. The main crisis here is the diagnostic management.

CAD in mammography provides a fast reliable second opinion to the physicians. The two most commonly detected signs of breast cancer are masses and calcifications. Detecting masses is a challenging task for radiologists and computers alike.CAD helps radiologists at this stage by marking FP's and TP's correctly and creating a clear boundary. The figure given below illustrates each stage of CAD in mammography.

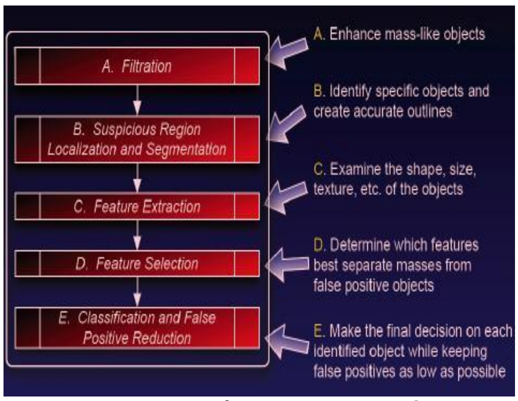

Fig: 4.1 Stages of CAD in mammography.

CAD in detecting lung cancer:

Lung cancer is the leading cause of cancer in both men and women. The interpretation of thoracic CT (Computed Tomography) scans for lung nodules is a challenging task for radiologists. The risks of FN detection and benign nodules being recommended for biopsy are high.

Computer assisted classification of malignant and benign nodules have been attempted and successful results were reported. Bayesian analysis and an artificial neural network to classify radiographic and clinical features achieved a high accuracy of lung nodule detection.

First stage is to isolate the lung nodules from the rest of the anomaly organs through segmentation. Nodule detection is performed only within the lung region. Rule based or other classifiers are used to classify nodules and FP's based on the extracted features. The suspected nodules are then marked on the CT scan and displayed as output of the CAD system.

Fig: 4.2Output of a CAD system for lung cancer

The above figure is an example for the ouput of a CAD system for lung cancer after detecting the affected area and marking it.

V. FUTURE OF CAD WITH PACS

In the future some CAD schemes will be included with some specific image modalities such as digital mammography, CT, MRI etc.Many other CAD schemes have started to assemble as packages and implemented as a part of PACS.For such a package to be used in clinical situations, it is important to reduce the number of FP's as much as possible. Though CAD schemes are proven to be successful in fields like mammography and detection of lung cancer, it is not widely commercialized. One of the main reasons for this is the need for a huge amount of database for segmentation and decision making. Researches studies and works are being carried out in this field to provide standard database package for specific CAD schemes. Studies have already proven that radiologists would prefer to profit from a direct analysis and assistance generated by a CAD without requiring any user interaction. This was in line with the demand for a technically integration with the PACS environment thereby avoiding data transfer, visualization of intermediate processing steps etc.

VI.CONCLUSION

CAD is a good clinical decision support system to assist physicians. It is a computerized way to reinforce the decision of the radiologist about a particular diagnosis. If there is enough data and a proper database, efficient and accurate decisions can be made by the physicians by saving a lot of time. it improves the accuracy in decision making by helping the doctors concentrate more ,only on the problematic areas. A time is not so far were we can see CAD applied in daily clinical works.

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