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Imaging Techniques: A Review

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ABSTRACT
Computed Tomography (CT) and Positron Emission Tomography (PET) are nowadays within the most employed imaging techniques for the screening and the identification of multiple pathologies, including lung cancer. Medical imaging is a field in continuous development to increase the employment of non-invasive techniques in diagnosis. For the screenings or detection of tumor masses, the use of these techniques can reduce the stress for the patient avoiding a surgical intervention and its risks. Moreover, imaging can be used as a preclinical tool for the decision making process for the most suitable treatment without the necessity of directly intervene in an invasive way.

Keywords: Computed Tomography, Positron Emission Tomography, Fluoro-Deoxy-Glucose, Kilo electron Volt

1. INTRODUCTION
1.1 Nodules

A solitary pulmonary nodule [12] (parenchymal, non-pleural nodule) is a small, round or egg-shaped lesion in the lungs. Juxtapleural pulmonary nodule is a small, worm-shaped lesion connected to pleura. (Figure 1.1)

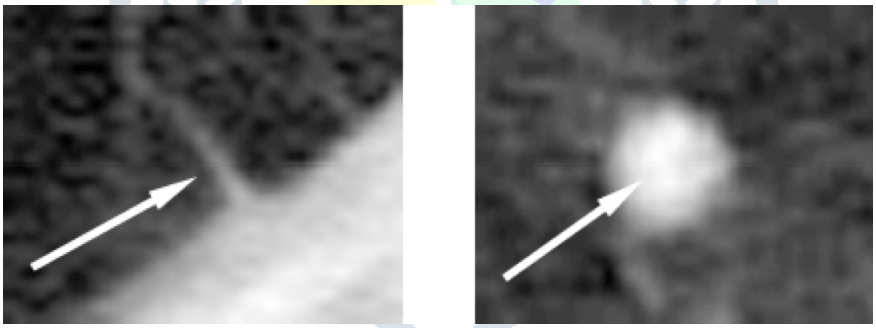

Figure 1.1: Nodule: juxtapleural nodule (left), parenchymal nodule (right).

Nodules are typically asymptomatic, and they are usually noticed by chance on a chest X-ray that has been done for another reason. They are usually smaller than 3–4 cm in diameter (no larger than 6 cm) and are always surrounded by normal, functioning lung tissue. Their intensity in CT scans is from -300 to 0 HU Nodules are fairly common abnormalities on chest X-ray images: nearly one of every 500 chest X-rays shows a newly diagnosed nodules [12]. In the United States, physicians are challenged each year by more than 150,000 new cases. Sixty percent of all nodules are benign. In certain geographical areas where the infectious agents (especially fungi) that cause nodules occur, the percentage of benign nodules increases remarkably (in some areas as high as 90% to 95%). Malignant nodules may be primary lung cancer tumors or metastases from other parts of the body. If the lesion is suspected to be benign, serial chest X-rays or CT scans may be taken on a regular basis for observation of the lesion. If the affected person is at high risk for lung cancer or if the CT scan appearance of the lesion suggests it is malignant, surgical removal of the lesion is recommended.

1.2 Tomography
Tomography is a method to obtain a cross-sectional images (transversal slices) of given object. In Computed Tomography images of objects (patients) are obtained by X-ray projection [11]. The mathematical basis for tomographic imaging was laid down by Johann Radon (December 16, 1887 (Litomˇeˇrice)–May 25, 1956). By applying his theorem slices of human body at various angles can be reconstructed.

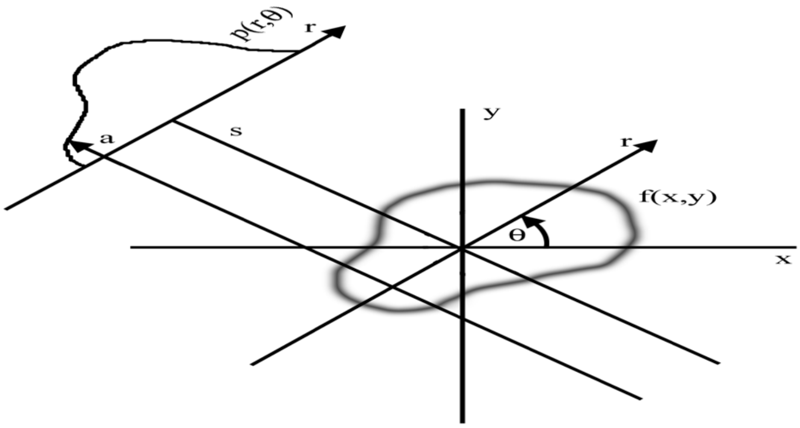

Figure 1.2: Parallel beam geometry

In X-ray CT, the line integral represents a logarithm of the total attenuation of the beam of X-rays as it travels in a straight line through the object.

2. IMAGING TECHNIQUES

In the medical field the identification of pathologies in the early stages is a crucial open problem that is at the base of a correct diagnosis and a subsequent decision of the most appropriate therapy. An invasive method for lung cancer detection is the employment of biopsy, which is an extraction of a tissue sample from the living patient [1]. It is clear that this approach is painful for the subject since it involves surgery. In order to avoid or reduce the employment of this dangerous technique some alternatives have been proposed, such as imaging based assessment. For example, in the past, one of the most used technologies was the X-rays imaging [2], while in recent years it has been used the F-fluoro-deoxy-glucose Positron Emission Tomography/ Computed Tomography imaging method, known also as FDG PET/CT. This examination allows the fusion of information from multiple sources giving, in this way, a more precise and accurate reproduction of the inside of the human body. Next Sections describe more in detail both the CT and the PET.

2.1 Computed Tomography

The Computed Tomography (CT) is a clinical imaging technique that exploits a X-rays beam in order to acquire signals, that after being elaborated by a computer, generate images generally called slices. The images are spatial representation of the attenuation coefficient of the rays in a section of the scanned object and can be considered as tomographic reconstructions of the body that contain more information compared to the traditional X-rays. The obtained images can also be stacked in order to form a 3-D reconstruction of the body district investigated, facilitating the visualization and the identification of organs or abnormal structures by a specialist [3]. The main difference between the conventional X-rays and the CT is that the first one uses a fixed source, while the CT has multiple sources that rotate around the patient inside a circular structure called gantry. A CT scan is a clinical examination that consists of a collection of multiple contiguous images of a specific part of the body in accordance to the area of interest of the clinician, as shown in Figure 2.1.

During the acquisition, the patient lies supine on a table that can be moved in or out of the gantry while the X-rays sources rotate around the subject [4]. The sources constantly release beams of X-rays that, passing through the human body and reaching digital detectors, which are positioned opposite to the sources, are able to create the images. The creation of a single 2-D slice is possible only after a complete rotation of the sources. In fact, in order to reconstruct the image, it is necessary to apply to the signals collected a mathematical procedure called back-projection reconstruction [5]. This step is done through the Radon transform, which, considering the angle of acquisition of each signal, is capable of mixing them in the most suitable way for reducing the creation of artifacts. This procedure is repeated for each movement of the table so that the entire region of interest is covered. The thickness of each slice can be decided by the physician, but it usually varies between 1 to 10 millimeters and the dimensions of each pixel are around few millimeters, allowing a very good spatial resolution [6]. Due to these intrinsic geometric characteristics, the CT is often preferred to the X-rays and has become a common tool for the identification of lesions and tumors in the abdomen, lungs, and head and also for inspection of the heart [7]. Consisting in the same technology of the X-ray, the CT can easily discriminate between hard and soft tissues due to the fact that structures such as bones stop the rays creating light spot in the image, while soft organs result in darker shape in the reconstructed image. For the aforementioned reasons, the CT is a good standard for structural investigation; however, Positron Emission Tomography, which gives details about the metabolic active structures, allows a more precise identification of tumors.

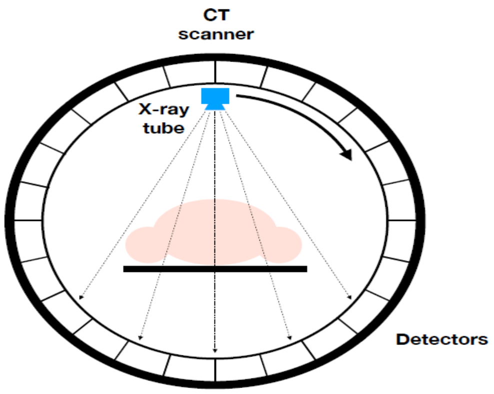

Figure 2.1: Basic scheme of Computed Tomography

2.2 The Positron Emission Tomography (PET)

PET is an imaging technology used in nuclear medicine that allows the assessment of structures functionalities employing radioactive substances. The PET creates 3-D images using radio-pharmaceuticals as tracers, which decay releasing positrons, which are then used for the creation of the images [8]. Positrons are particles that have similar mass to the one of electrons but with opposite charge, so passing through the human body they combine with the electrons and annihilate one another. This chemical reaction releases energy and two photons which produce two rays that, as shown in Figure 2.2, are shot in opposite direction and by colliding with the detectors are employed for the creation of the acquired images [9]. The main limitation of the PET is that it has an intrinsic low spatial resolution mainly due to the physical width of the detectors in combination with the decoding of the signal and the penetration. In fact, as highlighted in [34], if the rays are not perfectly perpendicular incident onto the detectors, they can interact with more than one detector so the signal can be associated to the wrong one degrading the resolution of the final image. The tracers used for a PET scan are formed by carrier molecules bonded to radioactive atoms and usually are administrated to the patient by injection, inhalation or ingestion [11]. The total amount of the tracer is so low that it does not influence the normal function of the system: for these reasons the PET is defined as physiologic tomography. This methodology is based on the emission of positrons _+ from the decay of the isotopes, which have a very short life, so, after a short path, (for example in lungs where there is the lowest tissue density), these positrons can reach maximum few millimeters. In the tissues, positrons annihilate with a negative electron generating in this way two rays of 511 KeV (Kilo electron Volt) emitted in opposite directions (180_) [9]. Positioning a couple of detectors is possible to exactly identify the line along which positrons have been emitted, shown in Figure 2.2. In addition, if two logic impulses are super imposed in time, the system recognizes annihilation and records also the integral value of the line joining the two activated crystals, which is then coded in the image. The aim of PET imaging technique is to identify cancer, monitor it and verify the efficiency of treatments, in addition to the detection of metastases. As tracer is usually used glucose because cells or tissues that have a high metabolic activity, such as dividing cancer cells, request a huge amount of energy, which means an increase in the glucose consumption. In fact, the more the cancer is aggressive, the more rapidly it will utilize glucose. For these motivation radiolabeled glucose is employed as tracer for

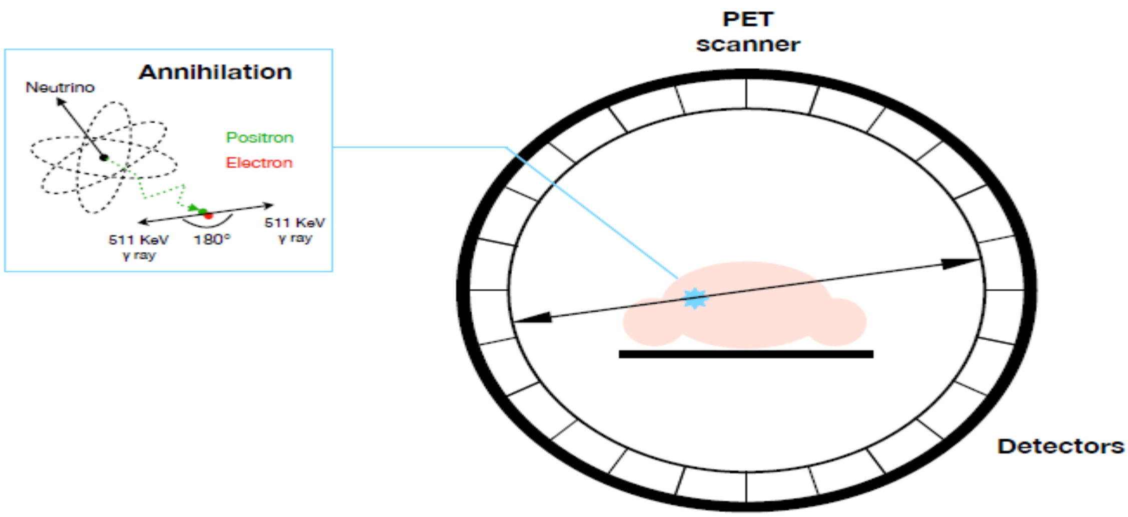

Figure 2.2: Basic scheme of Positron Emission Tomography

the detection of cancer and metastases spread in the body [12]. In the proposed work the tracer used for the PET acquisition is F-fluoro-deoxy-glucose (FDG). Summarizing what has been said above it is possible to conclude that the CT provides images with a good spatial resolution giving interesting details about geometry and mechanical properties of the internal structures. On the other hand, the PET, which lacks in spatial resolution, is able to highlight the metabolic active areas allowing the identification of the structures that are requesting a considerable amount of blood such as the heart or tumors. As confirmed by [13] scanning the same body district with both in one examination (PET/CT imaging) has become a highly employed tool for the identification and the staging of cancer all around the world thanks to the combination of anatomical (CT) and functional (PET) information. For the aforementioned reason, this thesis employs data acquired by the FDGPET/ CT, in this way, the proposed pipeline is able not only to analyze the selected dataset, but also other dataset acquired with this widespread technology.

2. LITERATURE REVIEW

Table 2.1: Findings of various techniques

S.No.	Author Name	Paper Title	Methodology	Research Gap
1	D.S. Elizabeth, 2012	Computer-aided diagnosis of lung cancer based on analysis of the significant slice of chest computed tomography image	A computer-aided diagnosis system capable of selecting a significant slice for the analysis	Five lobes of the lung can be segmented and the lobe in which the nodule exists can be identified to facilitate biopsy
2	Ritu Chauhan , 2013	A Knowledge Driven Model: Extract Knowledge from High Dimensional Medical Databases	Effective and efficient spatial clusters with domain specific knowledge for futuristic decision making	Spatial data sets corresponds to both spatial and non-spatial dominant attributes, hence knowledge discovery process accounts big challenge to extract spatial patterns from raw data
3	D.Lakshmi, 2013	Comparison of Texture Analysis in the differentiation of Carcinoma from Other Lung Abnormalities Using Low-Dose CT Images	A fully automated method of characterization of carcinoma from other lung abnormalities namely fibrosis and suspicious of tuberculosis	The number of essential features may be obtained by feature selection technique to show further improvement in the performance of classifier.
4	K.Balachandran,2013	Ensemble based optimal Classification model for pre-diagnosis of Lung cancer	Data mining approach is adopted here, to develop model for system study	Any error in the process may lead to a catastrophic situation
5	Lakshmi Devan ,2013	Non-Invasive Method of Characterization of Fibrosis and Carcinoma Using Low-Dose Lung CT Images	A fully automated method of characterization of carcinoma from other lung abnormalities namely fibrosis and suspicious of tuberculosis	The overall accuracy of the system to classify each disease pattern based on the typical ROIs is 89%
6	Jhilam Mukherjee,2014	Automatic Detection and Classification of Solitary Pulmonary Nodules from Lung CT Images	Method reduces variability in detection by automatic segmentation and classification of nodules	The same approaches can be extended to digital X-ray images towards a better cost effective solution
7	Muhammed Anshad PY, 2014	Recent Methods for the Detection of Tumor Using Computer Aided Diagnosis – A Review	Discussion on the necessary options, motivation, findings from the early developments and future expansions of CAD systems	
8	Ritika Agarwal, 2015	Detection of Lung Cancer using Content based Medical Image Retrieval	Review of the literature on detection of lung cancer using medical content based image retrieval	
9	Bram van Ginneken, 2015	Off-the-Shelf	OverFeat, trained	Despite its good

		Convolutional Neural Network Features for Pulmonary Nodule Detection in Computed Tomography Scans	for object detection in natural images, for nodule detection in computed tomography scans	performance, the systems built on CNN features alone perform worse than the highly tuned and optimized CAD system
10	Priyanka Kamra, 2015	Performance Comparison of Image Segmentation Techniques for Lung Nodule Detection in CT Images	Comparison between three segmentation techniques namely iterative thresholding, Region and Fuzzy Region based level set method	A hybrid technique can also be explored in future which detects all types of nodules perfectly
11	Barath Narayanan, 2016	Analysis of Various Classification Techniques for Computer Aided Detection System of Pulmonary Nodules in CT	Study of various feature selection methods for the CAD system framework	The number of nodules present in a dataset are too less when compared to non-nodules which might lead to poor covariance estimation of nodules, hence poor performance
12	Gawade Prathamesh Pratap, 2016	Detection of Lung Cancer Cells using Image Processing Techniques	1) Processing of distortion input image utilizing filter and segmentation 2) Morphological operations on CT picture	The proposed strategy can likewise be connected to identify some other malignancy like breast cancer, skin malignancy
13	Kazuki HIRAYAMA, 2016	Extraction of GGO candidate regions from the LIDC database using deep learning	1) segmentation of volume of interest from the chest CT image 2) first detection of GGO regions based on density and gradient which is selected the initial GGO candidate regions, 3) identification of the final GGO candidate regions based on DCNN (Deep Convolutional Neural Network) algorithms.	Some FP image after the final identification contains many those having a structure around the blood vessel branching points. if it is possible to identify the blood vessel branch as negative, further accuracy improvement can be expected.
14	Rotem Golan, 2016	Lung Nodule Detection in CT Images using Deep Convolutional Neural Networks	A CADe system for the detection of lung nodules in thoracic CT images. a CADe system for the detection of lung nodules in thoracic CT images	CADe system does not include any lung segmentation or additional FP reduction procedures, both of which are commonly used in other CADe systems and have the potential to improve the results of system
15	Atasi Sarkar, 2016	Multimodal Characterization of Radio logically Detectable Lung Lesions	Analyzing nuclear morphometric and intensity based differences between benign	

			and malignant lung lesions in a quantitative way	
16	Arnaud Arindra, 2016	Pulmonary Nodule Detection in CT Images: False Positive Reduction Using Multi-View Convolutional Networks	Pulmonary nodules using multi-view convolutional networks (ConvNets), for which discriminative features are automatically learnt from the training data	In the context of using the CAD system for lung cancer screening, the performance in terms of sensitivity should be improved
17	R. Kaviarasi, 2016	Recognition and Anticipation of Cancer and Non-Cancer Prophecy using Data Mining Approach	Tree algorithm and K-means clustering algorithms are used to separate cancer and non-cancer patient data based on the risk score	
18	Vijayalaxmi Mekali, 2016	Solitary Pulmonary Nodules Classification Based on Tumor Size and Volume of Nodules	Efficient CADe system using iterative thresholding method for segmentation and freeman chain code algorithm to repair the boundary of separated lung regions	Existing work can be extended to determine the survival rate and recurrence of the cancer
19	Alexander Kalinovsky	Lung Image Segmentation Using Deep Learning Methods and Convolutional Neural Networks	Segmentation of lungs in X-Ray chest images (Chest Radiographs) using Deep Learning methods and Encoder-Decoder Convolutional Neural Networks (EDCNN)	
20	G.Niranjana, 2017	A Review on Image Processing Methods in Detecting Lung Cancer using CT Images	Literature survey on various techniques that have been used in Pre-processing, nodule segmentation and classification	
21	Daniel Perez, 2017	Deep Learning for Pulmonary Nodule CT Image Retrieval - An Online Assistance System for Novice Radiologists	Developed an online content-based image retrieval (CBIR) system to assist novice radiologists in identifying lung Nodules	The accuracies reported here are not directly comparable to those in the literature
22	Kazuki HIRAYAMA, 2017	Extraction of GGO Regions from Chest CT Images Using Deep Learning	Extract the (Ground glass opacity) GGO using Deep Convolutional Neural Network (DCNN) based on emphasized images	There is a deficiency of GGO at the stage of extracting the initial shadow region
23	Sandipan Prasad, 2017	Fractal Analysis related to Tumour Growth in Lungs: A Review	A particular type of tumor growth in human lungs has been considered	
24	Lina Yu, 2017	iVAR: Interactive Visual Analytics of Radiomics Features from Large-Scale Medical Images	Novel visual analytics system, named iVAR, targeted at observing the comprehensive quantification of tumor phenotypes by effectively exploring a	Global information based approaches can be applied to improving the prognostic performance of radiomic signatures

			large number of quantitative image features	
25	Anton Dobrenkii , 2017	Large Residual Multiple View 3D CNN for False Positive Reduction in Pulmonary Nodule Detection	A novel method aimed at recognizing real pulmonary nodule among a large group of candidates	Methods presented in this work can be further extended to work with other kinds of 3D medical images in different tasks
26	Somaya Al Maadeed, 2017	Multispectral imaging and machine learning for automated cancer diagnosis	Review the current multispectral imaging based methods for automatic diagnosis of major types of cancer and discuss the limitations which are yet to be overcome	
27	Rabia Naseem, 2017	Recent Trends In Computer Aided Diagnosis of Lung Nodules in thorax CT Scans	Provides a comprehensive review of the existing automated methods of identifying lung nodules found in thorax CT scans presented in the recent era	
28	Suhani Sengar, 2017	Region-of-Interest Retrieval in Lung CT Images using Feature Point Maps	Novel method for retrieval of similar pathological cases in response to a query case in lung CT image database	In pre-processing, an adaptive thresholding algorithm is implemented that will separate the lung lesions from its background. The threshold is not a constant one and is solely determined by the local characteristics of the image
29	Xuechen Li, 2018	A Solitary Feature-Based Lung Nodule Detection Approach for Chest X-Ray Radiographs	A solitary feature-based lung nodule detection method	More features could be employed to identify real lung nodules
30	Ravindranath K, 2018	Early Detection of lung cancer by nodule extraction – A Survey	lung cancer detection by nodule extraction	Higher accuracy, sensitivity and reliability can be obtained by using Dynamic thresholding technique

3. CONCLUSION

CT and PET can be used separately but more and more frequently are jointed to combine information both from a structural and a functional point of view. In fact, the CT has a good spatial resolution giving the possibility to highlight the details of the inside of the body district investigated. The good resolution allows discrimination between the bones, the air inside the body and soft tissues; this classification is done exploiting the density of each structure, where a dense one appears lighter on the resulting image, while a hollow results as black. Considering the aforementioned characteristics the CT can be used for obtaining anatomical details that are useful for the identification of multiple diseases but cannot be enough when detailed functional information are needed. PET, on the other hand, thanks to the used radio-tracers, provides information about the metabolic activity of tissues. In fact, more active is the structure, more metabolic request it has and more blood containing the tracer it beckons resulting in a bright spot on the image.

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