

3D Coordinate Reconstruction From 2D X-Ray Images For Guided Lung Biopsy

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Abstract: - Biopsy is a diagnosis technique aiming at the detection of cancerous cells by removing a sample of tissue from the body. Advances in imaging systems lead to more precise biopsy results. Nowadays, Computed Tomography is one of the standard modalities for the purpose of imaging guided biopsy procedures. However, not all clinics and hospitals have access to Computed Tomography, especially those in developing countries. Conventional radiography, X-Ray, has capabilities to be used as an alternative imaging modality for image guided lung biopsy. X-Ray is more accessible since it is low-cost and is characterized by a lower radiation level compared to CT. Two X-Ray images were taken, one from anterior-posterior position and another from lateral position containing the cancerous cells being the target. The task of the physician then was to mark the target in each image so that subsequently the system will transfer the images into a three dimensional (3D) plot. In this 3D plot, the position of the targeted nodule relative to real life position could be measured. Results show that X-Ray guided biopsy is a functioning alternative for lung cancer biopsy.

Key-Words: - Biopsy, Image Guided Systems, Medical Imaging, X-Ray, 3D Coordinate, 3D Reconstruction

1 Introduction

WHO lists cancer as the leading cause of death worldwide, accounting 7.6 million death cases (around 13% of all deaths) in 2008 only[10],[19]. Among this number, lung cancer was recorded as the cause of around 1.37 million death cases[9]. Lung cancer symptoms usually require years to emerge and are only measurable when the cancer is already advanced. Due to that, some physicians recommend patients with high risk of lung cancer (i.e. smokers) an early screening in order to check the health status of their lungs. If screening results

show suspicious findings, like unidentified nodule inside the lung, physicians will forward with a biopsy procedure[8].

Lung cancer may not produce any noticeable symptoms at early stages. Many patients are diagnosed with lung cancer after the disease is significantly advanced. There are two types of lung cancer: non-small cell lung cancer and small cell lung cancer. Most patients diagnosed with lung cancer have non-small cell lung cancer. For each type of cancer, the outlook and the treatment may differ. Non-small cell lung cancer occurs in the airways of the lungs or the outer part of the lungs. It

usually grows slower than small cell lung cancers. Small cell lung cancers are typically in the bronchi, but can spread quickly to the rest of the body.

Biopsy is a medical diagnosis technique involving removal and examination of cells from various parts of the human body in order to detect the presence or extend of a disease. Lung biopsy is performed in order to help diagnosing lung diseases, like tumor and progressing lung cancer.

Advances in imaging technology, allow greater precision for targeting suspected lesions while avoiding non-important tissue such as blood vessels. Thus, it minimizes the risk and improves the accuracy of diagnosis. Imaging modalities being used to guide biopsy are Computed Tomography (CT), Fluoroscopy, CT-Fluoroscopy, Positron emission tomography (PET), PET-CT and Ultrasound-Guided biopsy. However, Magnetic Resonance Imaging (MRI) is also used in some cases. One of the most common imaging modalities used for lung biopsy is CT. This imaging modality provides relatively good results due to its imaging capability of the majority of existing lung structures. However, CT also raises concerns about the impact of radiation[11]. Although, the radiation level is considered being save, multiple and prolonged exposure can be dangerous. CT machines are usually not available in small hospitals, especially in developing countries.

Compared to CT, two-dimensional conventional radiography, widely known as X-Ray has a much lower rate of radiation. As for chest radiography, full chest CT exposes the patient with a radiation of ± 8.0 mSv, while X-Ray only exposes the patient with a value of ± 0.02 mSv for posterior anterior position and ± 0.04 mSv for lateral position[2]. X-Ray machines are also relatively more widespread compared to CT machines. Smaller institutions like hospitals in developing countries may have at least one X-Ray machine. It is possible to detect lung nodules by using simple X-Ray technology. On a chest X-ray of someone with lung cancer, there is usually a visible mass or nodule. This mass will look like a white spot on the lungs, while the lung itself will appear black. However, an X-ray may not be able to detect all forms of cancer or smaller lesions, the quality of results highly depends on the position and mass of the nodule.

2 Method

2.1 Computed Tomography

CT is the first choice for viewing the human anatomy without any superposition bias of the

organs. CT is the main imaging modality whenever it comes to fast three dimensional imaging. CT can display images in two dimensional slices or three dimensional volumes. CT is also capable of multiplanar reformation, a technique used to change the view of three dimensional volume into two dimensional planes relative to orthogonal axes[5]-[6].

2.2 Conventional Radiography

Conventional Radiography also known as Roentgen, deriving from Wilhem Roentgen, who is a scientist who discovered the X-Rays, which are used nowadays for radiography. Radiography is associated with the term X-Ray. X-Ray imaging can acquire large areas of human body, such as the complete chest. Unfortunately, its two dimensional nature displays the organs overlapped[1].

Noise also a prominent problem in conventional X-Ray images, there are different types of noise in X-Ray images caused by different sources. The noise is defined as the value added to the pixels of an image causing a change in the image details. Generally this problem is addressed by the use of low pass filters[16]

2.3 CT Guided Biopsy

CT-guided biopsy procedure starts with CT image acquisition. Physician then will detect the position of targeted nodules. Biopsy procedures should be executed without any delay after CT-Image acquisition. Further CT acquisition must be done before biopsy execution, in order to avoid the growth of the targeted nodule. As for any other intervention procedure, physicians should wear protective clothes and gloves[3].

Based on acquired CT images, the physician determines the best point to insert the needle. Then the patient is required to stay in position to facilitate the procedure for physician to reach that point[3].

The physician will find the most suitable needle entry point by analyzing data from the acquired CT image data set. The physician will mark the target and other important features, such as pulmonary blood vessels, which must be avoided by the needle. The skin entry point should be sterilised, a local anesthesia can also be delivered.



Fig. 1 Illustration of needle path in CT image

During insertion of the needle, the patient will be asked to control his breathing, the technique to do this should be taught and practised before needle insertion. The patient should completely suspend his breathing when the needle is advanced or withdrawn[3][7].

2.4 3D Reconstruction

X-Ray images do not provide three dimensional view of the patient's torso. However, it is possible to reconstruct a likeness of lung area and ribcage in three dimensional model. The 3D reconstruction help improve the visualization of the chest area without the need to use expensive 3D scanner system and can be combined with the existing computer aided disease detection technique to help with diagnosis. Since 2009, Koehler et al, had been researching about lung area and ribcage 3D reconstruction from 2D X-Ray images[12]. Using Posterior Anterior and Lateral view, the 3D models created from matching the vertices of a predefined 3D template with segmentation of lung area and ribs.

The first step of the 3D reconstruction using 2D X-ray images is to subtracts the ribcage from the images, then apply ribcage reconstruction. The next step is to segment the lung area, then reconstruct it by creating a mesh that encompasses the inside of the reconstructed ribcage, and then carves out the portion of that mesh, which corresponds to the lungs by extruding the segmented lungs up through it. Finally, the surface of chest area can be applied from the segmentation of the edge of the images.

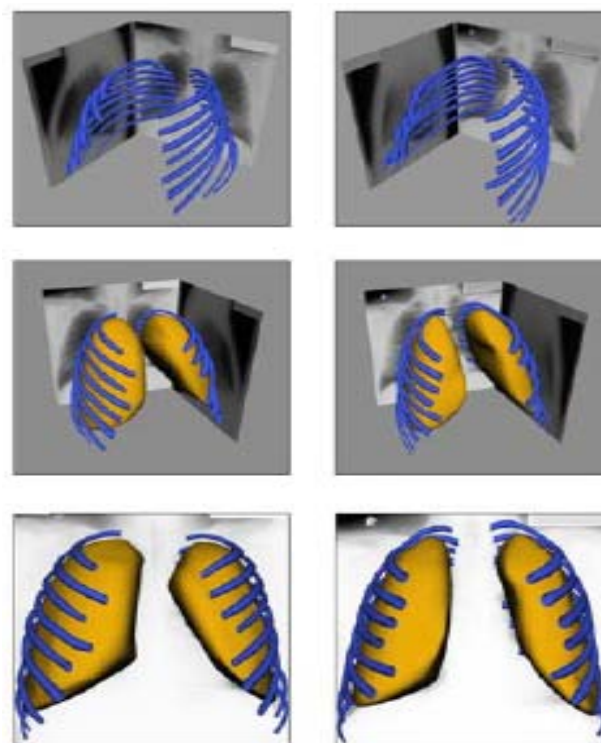


Fig. 2 Ribs and Lung Area Reconstruction[13]

2.7 Multiple View Geometry

Multiple view geometry also known as epipolar geometry depicts the geometrical relationship between 3D coordinate in real world and the projection of that point in 2D images from two or more views at distinct positions. In computer vision projective geometry is applied during the imaging process, which is customary to model the world as a 3D projective space with points at infinity. Similarly, the model for the image is the 2D projective plane. Central projection is simply a map from 3D projective space to 2D projective plane. If we consider points in 3D projective space written in terms of homogeneous coordinates $(X, Y, Z, T)^T$ and let the centre of projection be the origin $(0, 0, 0, 1)^T$, then we see that the set of all points $(X, Y, Z, T)^T$ for fixed X, Y and Z , but varying T form a single ray passing through the point centre of projection, and hence all mapping to the same point. Thus, the final coordinate of (X, Y, Z, T) is irrelevant to where the point is imaged[15].

Most of general imaging projections are represented by an arbitrary 3×4 matrix of rank 3, acting on the homogeneous coordinates of the point in 3D projective space mapping it to the imaged point in 2D projective plane. This matrix P is known as the camera matrix.

It is possible to remap the point from 2D projective plane to 3D projective space using information acquired from two or more 2D Images. This considers a set of correspondences $x_i \leftrightarrow x_j$ in two images. It is assumed that there exist some

camera matrices, P_i and P_j and a set of 3D points x_i that give rise to these image correspondences in the sense of $P_i x_i = x_i$ and $P_j x_i = x_j$. Thus, the point x_i projects to the two given data points. If the camera or the points are known, it is possible to reconstruct a 3D model from the images [15].

In X-Ray, objects appear overlapped to each other, thus making it difficult to compare one view with another view from a different angle. However, modern X-Ray is capable of accurately measuring the difference in scale between real life objects and projection in a 2D plane, thus even the camera matrix (point of view) from an X-Ray image is hard to be measured, the points in X-Ray images are easily scaled to the 3D projective space.

2.6 Proposed System

The use of chest X-Ray images, instead of CT images, as the media for defining the entry point and target is proposed here. Two X-Ray images will be used, one is the posterior anterior X-Ray capture of the chest and the other is taken from the lateral left of the chest.

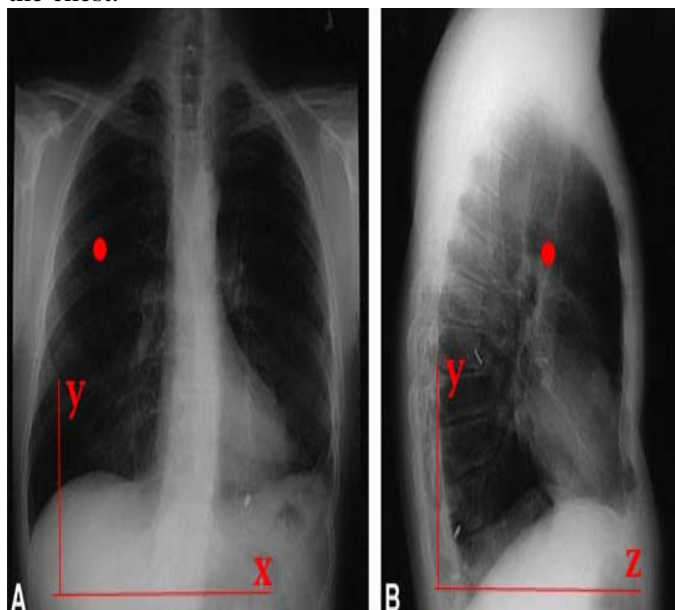


Fig.3 Biopsy target in anterior posterior "A" and lateral "B" X-Ray image.

Here, the physician can pick the targeted point in each image. The system then will register all targeted points in both images and visualize them in a 3D plot.

The formula to register each point to the respective point in a 3D Plot, is as follows:

$$\alpha = \frac{x1}{height} \quad (1)$$

$$\beta = \frac{(y1 - y2)}{width} \quad (2)$$

$$\gamma = \frac{x2}{height} \quad (3)$$

$$x' = -0.5 + \alpha \quad (4)$$

$$y' = \left(\frac{y}{height} \right) - 0.5 + \beta \quad (5)$$

$$z' = \left(\frac{x}{width} \right) - \gamma \quad (6)$$

3 Experiment

A prototype of the system has been developed. However, this prototype lacks in the capability to accurately guide the physician in his execution of the biopsy procedure. Nevertheless, this prototype shows the possibility of conventional X-Ray as a functional alternative towards CT guided lung biopsy.

This prototype was developed under the assumption that X-Ray images are in DICOM format, which includes the pixel spacing information that needs to be transformed from pixel distance into metric distance.

Furthermore, this prototype was developed using GDCM library in order to read DICOM, OpenCV library for pre-processing purposes and OpenGL library for visualization.

Simple experiments have been carried out in order to test the prototype system. X-ray images of a person were acquired, a small coin was attached to the subject's back. From the posterior anterior image view, the coin looks like a bright circle, while from the lateral image view, it looks like an ellipse object. The user of the system will digitally select the object of interest in both images. The system then puts both images in a three-dimensional point of view. By crossing the point of interest in both images, the position of the target can be seen in three-dimensional view. For better visualization, 3D reconstruction techniques should be employed, however, in this stage of study, the features had not been realized yet.

In this experiment, the targeting of the nodule is delegated to the user. The user will select the target in both posterior anterior view and lateral image. The system will then save the pixel position of the selected target, x_1 and y_1 are the target pixel position in the posterior anterior image, while x_2 and y_2 are the target pixel position in the lateral view. The

system computes the position of the target in 3D plot using the formula shown from Eq. 1 until Eq. 6 and visualizes the cross-point between posterior anterior image and lateral image.

In this experiment, the targeted nodule is simulated with a coin attached to the volunteer subject body. If the coin is selected in posterior anterior image, the pixel position captured is (1684,1469), which means $x_1 = 1684$ and $y_1 = 1469$. If the coin gets selected in lateral image view, the pixel position captured will be (1612,1429), which means $x_2 = 1612$ and $y_2 = 1429$. In the 3D plot, the position of a point is measured from 0 to 1, with 0 is the starting point and 1 is the end point. Applying the formula to the pixel position of x_1, y_1 and x_2, y_2 results of 3D plot positions will be $x' = 0.174$, $y' = -0.464$, and $z' = 0,787$. Using the pixel spacing information from images metadata, the real life position of target relative to chest surface can be measured. The distance of the targeted from the chest surface is 283.248mm from the right side of the chest and 196.056mm from the front of the chest.

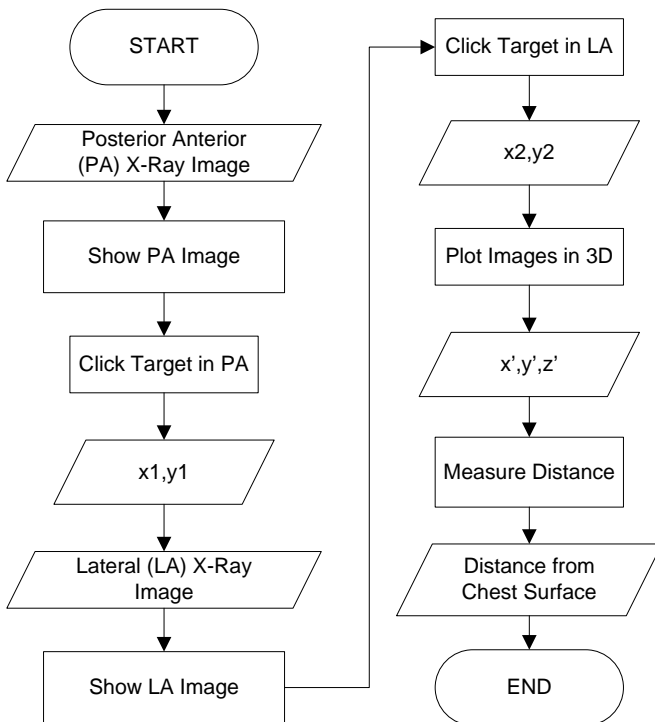
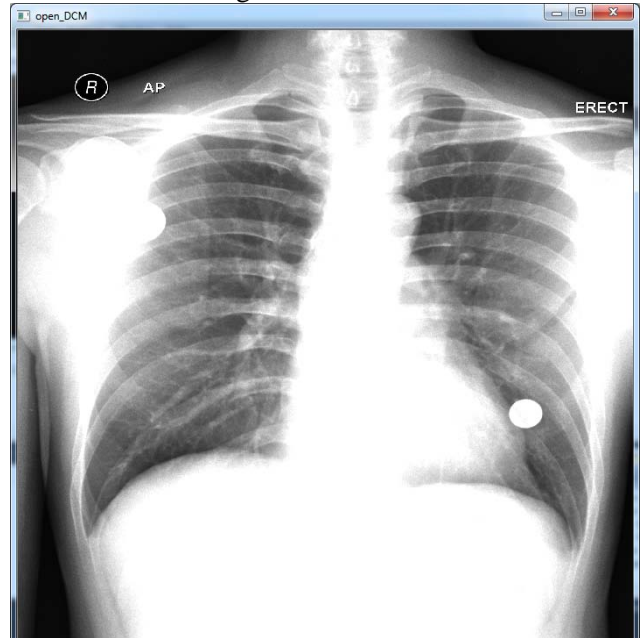


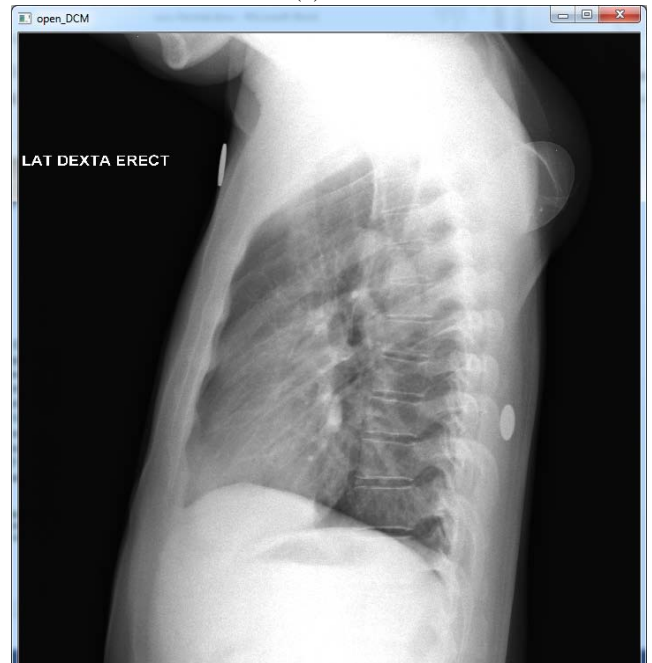
Fig. 4 Systems Flowchart

Figure 5 shows the visualization of the system. Here, the system shows both posterior anterior images as well as lateral images alternately. The user selects the target in the posterior anterior image as well as the lateral image, the system then computes the position in a 3D plot and visualizes

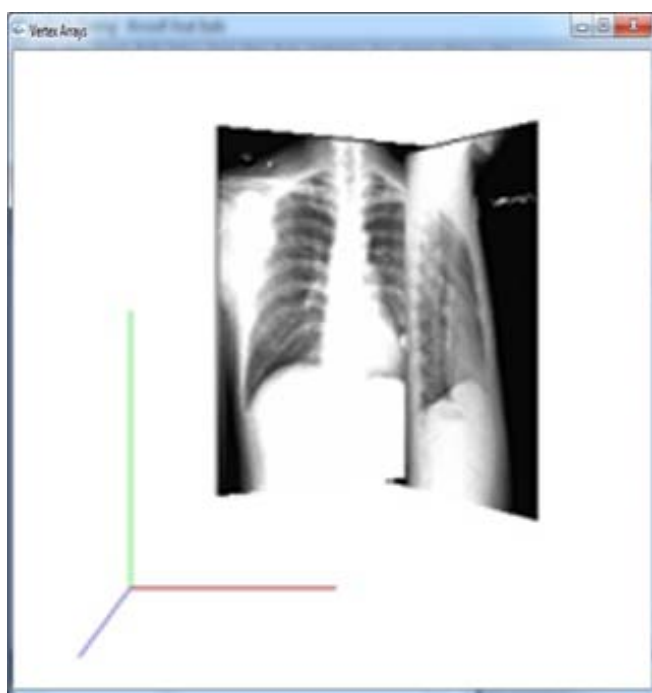
the cross-point between the posterior anterior image and the lateral image. The system also measured the distance of the target from right side and front side of the chest. This distance can be used as a guide to measure the position and how deep a needle should be inserted into lungs.



(a)



(b)



(c)

Fig. 5 System Output Data being (a) anterior posterior chest X-Ray image, (b) lateral chest X-Ray image and (c) target position in 3D.

4 Discussion

Early lung cancer screening for patients with a high risk of lung cancer, can save lives. Experiments show that a target position in 3D plot can be computed from posterior anterior image and lateral image of 2D X-Ray. X-Ray shows effective capabilities to be used as an less radiating alternative. Furthermore, it and can point the target in X-Ray data. However, the system still requires more measurements than CT guided systems. It can be concluded that such a system will only have as much success as any CT when physicians face the same comfort using the proposed system as they face while using CT guided systems. Another drawback is that the developed prototype system lacks in the ability of recognizing ribs and pulmonary vessels, while CT guided systems can easily point ribs and large pulmonary vessels so that the physician can easily plan a safe needle path in order to avoid harm to both ribs and large pulmonary vessels. Future works on the developed system should address this issue and include capabilities to display important features such as ribs and pulmonary vessels clearly.

5 Future Works

It is clear from the experiment that CT guided biopsy is easier to perform. While X-Ray shows capabilities to be used as an alternative and has ability to point the target, the system still requires

more measurements than conventional CT guided systems. It is highly recommended to develop the system so that the physician faces the same comfort using X-Ray as CT guided systems. Since the prototype system is also not capable in recognizing ribs and pulmonary vessels it gets difficult for the physician to plan a needle path in order to avoid damage to both ribs and pulmonary vessels. The developed system should address this issue and show capabilities to highlighten ribs and pulmonary vessels clearly.

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