Lung Intervention by Using CT Fluoroscopy with Repository Framework

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***Abstract*— CT-fluoroscopy (CTF) is an efficient imaging method for guiding percutaneous lung interventions such as biopsy. During CTF-guided biopsy procedure, four to ten axial sectional images are captured in a very short time period to provide nearly real-time feedback to physicians, this traditional CTF-guided intervention procedure may require frequent scans and cause unnecessary radiation exposure to clinicians and patients. In addition, CTF only generates limited slices of images and provides limited anatomical information. To better utilize CTF guidance, we propose a fast CT-CTF registration algorithm with respiratory motion estimation for image-guided lung intervention using guidance. With the pre-procedural exhale and inhale CT scans, it would be possible to estimate a series of CT images of the same patient at different respiratory phases.. In this new system, CTF is used as a nearly real-time sensor to overcome the discrepancies between static pre-procedural CT and the patient's anatomy, so as to provide global guidance to reduce the number of CTF scans needed. In the experiments, the comparative results showed that our fast CT-CTF algorithm can achieve better registration accuracy.**

***Index Terms*— Image Processing, Computed Tomography fluoroscopy, Repository motion framework.**

I. Introduction:

A. *Objective of the project:*

Lung cancer is considered to be as the leading cancer-related cause of death worldwide, with 1.35 million new cases and 1.18 million deaths per year. It is estimated that about half of the lung cancer cases are peripheral. In addition to detect abnormal nodules from CT imaging, biopsy through percutaneous intervention of peripheral lung cancer is currently the standard procedure for diagnosis and confirmation of lung cancer. In clinical practice, the major difficulties in percutaneous lung intervention are targeting accuracy, efficiency of the procedure, and complications. When dealing with small and relatively deep lesions, accurately targeting the lesion becomes challenging due to patient's respiratory motion. Currently, multimodality imaging techniques have been adopted to alleviate the burden. Fluoroscopy takes real time X-ray images but only provides 2D image information. Ultrasound is an alternative real-time imaging modality and can provide instant visualization of the chest structures. It is, however, not suggested for lungs and only applicable to lesions close to the diaphragmatic surface due to its imaging depth and the rib effects. Real-time MRI scanners are still too expensive to be used in the clinics for guiding interventions. Therefore, conventional CT is currently a common guidance tool and is widely used in percutaneous lung biopsy. It, however, provides very limited guidance for interventions because of lack of real-time feedback of lung anatomy during the procedure. Since the guidance relies on a static CT, it might generate larger error due to the dynamic deformation of lung parenchyma during respiratory cycles. Therefore, a precise prediction of the movement of the lung from real-time sensors to better match patients' anatomy would be highly desirable for more accurate localization.

CT fluoroscopy (CTF) combines the advantages of both conventional CT and fluoroscopy and has been recognized as an efficient and convenient tool for image-guided lung intervention percutaneous. During CTF-guided biopsy procedure, four to ten axial sectional images are captured in a very short time period by the traditional CT scanner to provide physicians nearly real-time feedback about patient's anatomy. These CTF images can provide guidance to adjustment of the needle, as it is advanced towards the target lesion. In current clinical practice, physicians normally advance the needle using CTF as guidance by first asking patients to hold breath, pressing the foot paddle of the CT scanner to capture the CTF images, and then advance the needle accordingly. There is normally a 15 to 30 second time window dependent on how well the patient can hold breath. Physicians can repeat such procedure until the needle hit the target lesion for biopsy. This procedure may require frequent scans and cause unnecessary radiation exposure to clinicians and patients. In addition, it also has limited response to respiratory movements and only provides narrow local anatomical dynamics.

a) Basic concepts:

Biomedical engineering is a discipline that advances knowledge in engineering, biology and medicine, and improves human health through cross-disciplinary activities that integrate the engineering sciences with the biomedical sciences and clinical practice. It includes:

1. The acquisition of new knowledge and understanding of living systems through the innovative and substantive application of experimental and analytical techniques based on the engineering sciences.
2. The development of new devices, algorithms, processes and systems that advance biology and medicine and improve medical practice and healthcare delivery.

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Biomedical engineering has only recently emerged as its own discipline, compared to many other engineering fields. Such an evolution is common as a new field transitions from being an interdisciplinary specialization among already-established fields, to being considered a field in itself. Much of the work in biomedical engineering consists of research and development, spanning a broad array of subfields. Prominent biomedical engineering applications include the development of biocompatible prostheses, various diagnostic and therapeutic medical devices ranging from clinical equipment to micro-implants, common imaging equipment such as MRIs and EEGs, regenerative tissue growth, pharmaceutical drugs and therapeutic biological.

Biomedical engineering can be viewed from two angles, from the medical applications side and from the engineering side. A biomedical engineer must have some view of both sides. Biomedical engineering

(BME) is the application of engineering principles and design concepts to medicine and biology for healthcare purposes (e.g. diagnostic or therapeutic). This field seeks to close the gap between engineering and medicine: It combines the design and problem solving skills of engineering with medical and biological sciences to advance healthcare treatment, including diagnosis, monitoring, and therapy.

Computed tomography fluoroscopy:

Computed tomography (CT) fluoroscopy is one of many recent advances in medical diagnostic imaging. With the advent of computers capable of processing large amounts of information almost instantaneously, and the development of slip-ring technology, CT fluoroscopy has become a useful tool for physicians performing interventional procedures. The anomaly in the patient is located with conventional CT imaging, then the physician uses CT fluoroscopy to track the position of a biopsy needle. Simple biopsies require only a few seconds of CT fluoroscopy on-time, but during more complicated procedures, the patient may be exposed to five minutes or more of radiation exposure. CTF guidance is especially helpful in lumbar epidural injections, because insertion of the needle an approach can be planned to access the epidural space and avoid any osseous structure, even in patients with spinal stenosis or intralaminar space narrowing. On rare occasions, a bolster may be necessary to open the intralaminar space, but this is generally not necessary even when a path is not visible on any one section, because evaluation of adjacent scout images will allow appropriate needle angulation to enter the epidural space. Visualization of the spinal contents before insertion of the needle also enables recognition of potential causes of inaccurate needle placement or procedure failure. These include synovial cysts or cysts of the ligamentumflavum, severe spinal stenosis, as well as epidural scarring and thecal sac deformity in postoperative patients.

Image guided Lung intervention:

Lung cancer is the leading cause of cancer-related death in the United States, with more than half of the cancers are located peripherally. Computed tomography (CT) has been utilized in the last decade to detect early

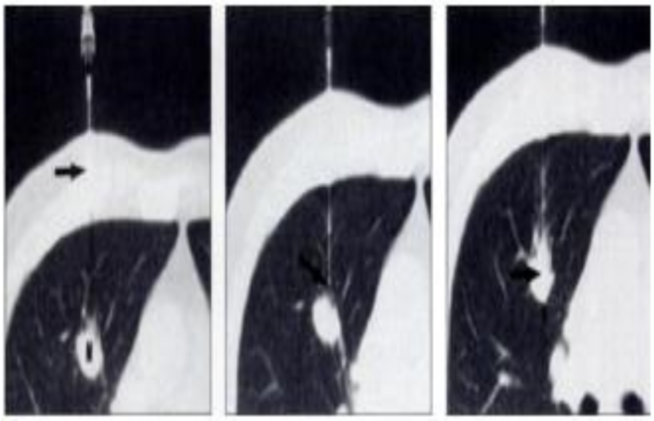

Fig 1: Lung Cancer motion pathway direction

peripheral lung cancer. However, due to the high false diagnosis rate of CT, further biopsy is often necessary to confirm cancerous cases. This renders intervention for peripheral lung nodules (especially for small peripheral lung cancer) difficult and time-consuming, and it is highly desirable to develop new, on-the-spot earlier lung cancer diagnosis and treatment strategies. **Image-guided intervention** is the general term used for any ***surgical*** procedure where the ***surgeon*** employs tracked surgical instruments in conjunction with preoperative or intra operative images in order to indirectly guide the procedure. Image-guided surgery is part of the wider field of ***computer-assisted surgery*.** Most image-guided surgical procedures are ***minimally invasive***. A field of medicine that pioneered and specializes in minimally invasive image-guided surgery is ***interventional radiology***. Image-guided surgery was originally developed for treatment of brain *tumors* using ***stereotactic surgery*** and *radio surgery* that are guided by ***computed tomography*** (CT) and *magnetic resonance imaging* (MRI) using a technology known as the ***N-localizer***. However, Image-guided surgery has found widest application when applied to surgery of the ***sinuses***, where it helps to avoid damage to brain and nervous system. The system was developed for on-the-spot interventional diagnosis of peripheral lung tumors by combining image-guidance and molecular imaging. The system can be potentially applied to human trials on diagnosing and treating earlier stage lung cancer. For current clinical applications, where a biopsy is unavoidable, the system without contrast agents could be used for biopsy guidance to improve the accuracy and efficiency.

II. System Design:

A. System Configuration:

a) Hardware Requirements:

- System : Pentium IV 2.4 GHz.
- Hard Disk : 40 GB.
- Monitor : 15 VGA Color.
- Mouse : Logitech.
- Ram : 512 Mb

b) Software Requirements:

- Front End :MATLAB

B. System Analysis:

a) Existing System:

Limited imaging of lung function is possible with methods that use ionizing radiation, such as computed tomography (CT) and lung scintigraphy. Methods using magnetic resonance (MR) are preferable because they do not involve ionizing radiation. At first, MR methods were difficult because of the lack of protons and artifacts caused by in homogeneity in the lungs. Recently, new techniques have allowed static and dynamic lung imaging with MR. The existing methods that allow functional imaging of the lung and describe new developments in functional MR imaging (MRI). From being almost invisible to MRI, lung images with MR may soon radically affect the way we assess the function of the lung and the pulmonary circulation.

In existing system used to improve the diagnostic accuracy of CT guided biopsy of small lung nodules with the aid of frozen-section histopathology diagnosis. All biopsy procedures were performed by interventional radiologists. The level of the needle entry site was determined from a review of the preliminary scans. With the aid of a localizing grid applied to the patient. The site of needle placement was marked with indelible ink and prepared with a povidone-iodine solution. Local anesthetic, a 1% solution of lidocaine was given and a 68-mm 23- gauge needle was inserted into the skin entry site to a depth not penetrating the pleura.Percutaneous lung intervention is targeting accuracy, as well as its efficiency and complications. When dealing with small and relatively deep lesions, lesion targeting can be extremely challenging due to patient's respiratory motion and also use the MRI as an interventional imaging modality is still limited due to a number of implementation issues such as incompatibility with conventional interventional instruments, high cost, and the complexity of the procedures.

b) Proposed System

Because the pre-procedural CT covers the entire or most of the lung region, and there are only 4 to 10 slices in the CTF images, the current 3D to 3D registration or 3D to 2D registration algorithms do not fit this kind of application. Because there is only limited number of slices for CTF, the deformation consideration in x and y direction should be different from the z direction. On the other hand, although the slices covered by CTF imaging can be precisely aligned, the deformation of the rest slices can only be interpolated or estimated. To solve these problems, we propose a CT-CTF registration algorithm to deal with limited number of slices. More over such CT-CTF registration can be incorporated in the framework of motion estimation so that the information of patient's respiratory motion can be embedded in the algorithm. The algorithm is performed in the following steps. First, the pre-procedural lung CT scans are captured in both exhale and inhale phases. Then, longitudinal deformation between the exhale and inhale phases can be calculated by performing a 3D/3D image registration. A series of CT images can then be estimated by scaling the longitudinal deformation to simulate the CT images between exhale and inhale phases. This process can be performed prior to the interventional procedure.

During the interventional procedure, when an intra-procedural CTF is captured, the breathing phase can be determined by matching the CTF with the above estimated serial CT images using least squares differences. Next, the CT-CTF registration is performed to warp the inhale CT image onto the CTF space by considering a combined deformation, i.e., first deforming the inhale CT image onto the intermediate CT that best matches the respiratory phase, and then deforming onto the CTF space. Notice that the longitudinal deformation of the intermediate CT caused by respiratory motion is known, and the goal is to estimate the elastic motion between such motion-compensated CT and the CTF. This process requires fast computation to satisfy intra-procedural guidance while the patient is holding breath.

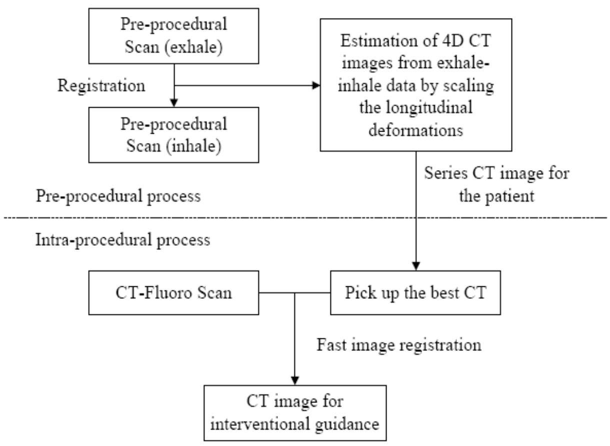

Fig 2: Block Diagram Representation

C. SystemArchitecture:

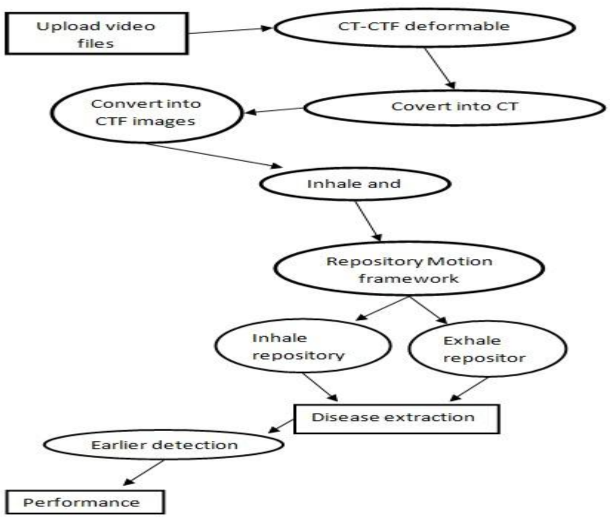

Fig 3: Architecture Flow Diagram

D. Module Description:

Upload Video:

In this module we upload video to obtain real-time moving images of the internal structures of a patient through the use of a fluoroscope. In its simplest form, a fluoroscope consists of an X-ray source and fluorescent screen between which a patient is placed. The uploaded videos are used to guide the lung interventional procedure.

Frame Conversion:

This module is used to convert the videos into frames. Each frame is known as realistic moving images based on standard size using video File reader. All frames are in the form of CT image. CT images can't be used to analyze the motions in images.

CT-CTF Registration algorithm:

Using CT-CTF registration algorithm to identify the exhale and inhale positions in the lung. Exhale of lung is the flow of the ***respiratory*** current out of the organism. In humans it is the movement of air out of the bronchial tubes, through the ***airways***, to the external environment during ***breathing*** which lower the rib cage and decrease thoracic volume. Inhale of lung image is the flow of air into an organism. It is a vital process for all human life. In humans it is the movement of air from the external environment, through the airways. We separate the inhale and exhale lung images based motion. The registration algorithm converts the CT images into CTF images.

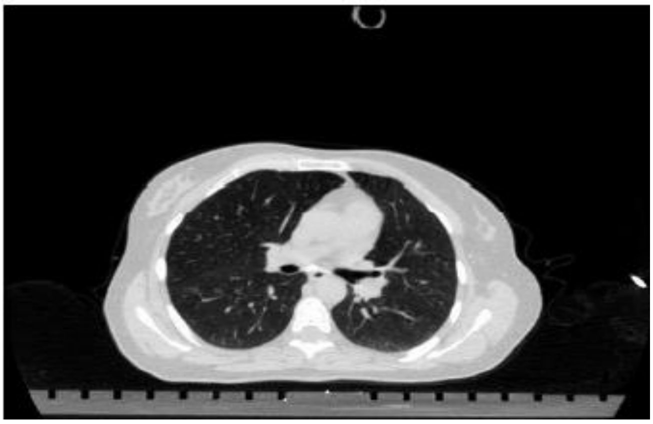

Fig 4: Intermediate stage

Repository motion framework:

The CT-CTF algorithm can rapidly register CT with CTF images. Since only the slices covered by CTF images can be precisely aligned, the deformation of the rest slices can only be estimated by gradually decreasing and expanding the deformation field outside the boundary CTF slices along z-direction. Therefore, if there is a motion discrepancy between the pre-procedural images and CTF, a gradual transition or gap might be notable. In order to estimatesuch deformation and accomplish more accurate registration, we propose to incorporate MC into our CT–CTF registration.

Performance evaluation:

We evaluated the performance of CT-CTF registration with motion compensation. To do so, we first used registration algorithm to calculate the longitudinal deformation between the exhale and inhale images $I1$ and $I2$, and the resultant deformation can be denoted as $\boldsymbol{f}2\rightarrow1$. Then, the deformation was scaled to obtain a number of intermediate deformations, $\boldsymbol{f}t=(T-t)/T\cdot\boldsymbol{f}2\rightarrow1$, and corresponding intermediate images It, t=1,2,…,T. Then, the image intensity-based similarity between the CTF image simulated above and intermediate images It can be calculated on the available CTF slices. The best intermediate image was then selected as the one that matches the respiratory phase of the input CTF. Based on the evaluation we identify the nodules in lung and provide reduce able false rate diagnosis report.

Fig 5: Nodule Detection

III. Conclusion:

In this project, we proposed a fast CT-CTF registration algorithm with motion estimation for image-guided lung intervention. With pre-procedural exhale and inhale CT scans, it is possible to estimate a series of CT images at different respiratory phases of the same patient. Then, once the real-time captured intra-procedural CTF images are captured during the intervention, our algorithm can pick the best respiratory phase and performs a fast deformable registration. Within one second a 3D CT image can be generated to match the CTF. This allows reduce able time for interventional radiologists with 3D image guidance during the breath holding. Different from traditional 3D-3D or 2D-3D algorithms, our CT-CTF algorithm models the deformation in the axial plane. The comparative results showed that the proposed CT-CTF approach overcomes discrepancies between static pre-procedural/diagnosis CT and the patient's anatomy and corrects the respiratory motion and image deformations. In this project, we estimated the intermediate CT images by sampling the longitude deformation between inhale and exhale status. To better estimate the serial CT images, in the future, other methods nonlinear motion regression model may be used.

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