A dual modality of cone beam CT and electrical impedance tomography for lung imaging

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Abstract. Electrical impedance tomography (EIT) is a new and emerging tomographic imaging system, which is able to provide high temporal resolution with low spatial resolution. In past few years, the EIT has been extensively studied for lung monitoring. Cone beam CT (CBCT) is an imaging system used in radiation therapy unit. The CBCT suffers from motion artefacts, making treatment planning inaccurate. This problem is very severe in lung cancer therapy. In this study a dual modality of EIT-CBCT has been proposed. Feasibility of such a dual system has been investigated using preliminary simulated phantom data. The motion information is extracted from the EIT images and has been used to compensate for the motion in CBCT through our recently developed iterative image reconstruction for CBCT. The results show that blurring artefacts around a tumour can be reduced for the motion compensated images using this dual modality combination. The dual EIT-CBCT imaging benefits from complementary high spatial resolution of CBCT and high temporal EIT resolution.

1. Introduction
Imaging systems have been integrated into radiation therapy systems for improving the accuracy of tumour localization during the treatment. CBCT is one of the main imaging systems that have been used in conjunction to linear accelerators[1]. One of the most challenging problems in CBCT is the patient and organ movement during imaging leading to motion artefacts and target tissue misalignments [2-5]. Radiotherapy of the lung tumour is heavily affected by respiratory movement [4, 6], making radiation therapy of lung cancer very ineffective. High precision radiotherapy is required for accurate tumour localization just prior and during the treatment [7]. Many methods have been investigated for correcting the respiratory artefacts. One of them is motion compensated CBCT, which uses estimated motions from patients for compensating in image reconstruction process. Motion artefacts are reduced and the quality of motion compensated image can be improved. A further problem is that CBCT cannot monitor respiratory lung and tumour movement during the radiation treatment session so that a movement monitoring system can be helpful then.

In this paper, a new approach using EIT imaging as motion monitoring system has been investigated. EIT is an imaging technique that can provide images of interior of the thorax by external measurement of electrical impedance at the surface electrodes. EIT has already been used in critical care units for lung monitoring [8]. The proposed approach is to combine EIT with CBCT taking advantage of high temporal resolution of the EIT and high spatial resolution of CBCT. Our preliminary investigation results and method follows here.
2. Motion compensation in CBCT
A three dimensional simulated phantom (256 × 256 × 256 voxels) has been created and used in this study. The phantom consists of two big rectangular objects with a small rectangular object. Both objects have different x-ray absorption properties. Projection data were obtained over 360 degrees and, then, were reconstructed with algebraic reconstruction technique (ART) of 10 iterations for 0.015 relaxation parameter [11]. A moving phantom has been created by applying a sinusoidal signal of 20 mm (figure 1(a)) in anterior – posterior (AP) direction during projection data acquisition. This motion information was compensated throughout the image reconstruction process by sorting the reconstructed image to original position during iterations. We assumed that we know the motion with some degree of certainties.

![Figure 1](image)

**Figure 1.** (a) Motion signal, (b) Reconstructed image of simulated phantom at z = 135 (a) with 20 mm of AP motion and (c) Motion – compensated image.

Figure 1(b) shows the reconstructed image ignoring a priori knowledge of the motion. It can be seen in figure 1(c) that motion blur is reduced in the reconstructed image with motion compensation from the fifth iteration of ART. The boundaries of a small rectangular object in motion compensated images can be seen more clearly than the boundaries of it on the image. We have tested this in several conditions and the results shows that even motion information with an error can be very helpful in reducing the artifacts in CT images. This suggests that a motion extracted from an EIT image could be good enough to improve this blurring effect due to the organ motions, which will be shown in the next section.

3. Combined CBCT/EIT study
In proposed dual modality approach, the EIT is used to dynamically image the boundaries of large organ (lungs). This provides information on the motion that can be fed into CBCT iterative image reconstruction. A simulated phantom consisting of two spherical objects with 30 mm of radius was moved by 40 mm of motion in AP direction during imaging by EIT system. Figure 2 shows the EIT images in different times, the position of spheres were also in different positions. Several methods are used for motion estimation such as optical flow methods and block matching techniques [9]. In this study centres of spheres were defined from the first EIT image as original positions and, then, were followed in further images for extracting movement data. The average of the motion data detected from both spheres was calculated and used for compensation. Projection data were collected over 360 degrees. The same reconstruction algorithm parameters as motion compensation study were used.

Figure 3 (a) and (b) are the CBCT image of two spheres without motion and with motion, respectively. Figure 3(c) is a motion compensated image by using motion signal extracted from EIT images. It can be seen that image blur is clearly improved on the image with motion compensation comparing with the motion image. The boundaries of spherical objects on the compensated image (c) are sharper than the boundaries of them on the motion image (b). This can be seen in 1D plot of column 68 of all these images in figure 4.
Figure 2. EIT images of spherical object at (a) the lowest position, (b) the original position and (c) the highest position.

Figure 3. CBCT images of two spheres (a) without motion, (b) with 40 mm of motion in AP direction and (c) motion compensation by using EIT motion signal.

Figure 4. Image row plots for figure 3 at y=68 (centre of left sphere).
4. Conclusion
Radiation therapy is a primary tool for the treatment of lung cancer which is heavily affected by respiratory movement. The respiration monitoring system is required for tracking the respiration movement. Motion compensation by using EIT motion data through iterative algorithm of CBCT can reduce motion artefact for CBCT images. Boundaries of objects could be clearly seen on motion compensated images. Image quality is improved. Estimated motion information taken from EIT images can be used to compensate the motion for CBCT system. The fact that the EIT provides an internal image of movement makes this multimodality superior to other alternative techniques that are based on estimating motions from ECG and respiratory signals. This paper shows preliminary results in EIT-CT combination. The information about the motion of interior structures are extracted from low resolution EIT images and entered in CBCT image reconstruction through an iterative algorithm developed for volumetric CBCT. We have tested the motion detection algorithm using experimental data from magnetic induction tomography. Further validation is needed using in-vivo lung EIT images. In our continued effort we will establish a patient specific EIT model using anatomical information obtained from diagnostic CT. It is important to notice that the EIT only provides information about the (dynamical) movement of the larger organs (lungs) and do not have to capture more detailed structures. A shape based algorithm will be used to efficiently recover this boundary movement from EIT data [10]. Although the method discussed here is proposed for CBCT, the motion information generated by EIT can be used for conventional CT imaging.

References:
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