Research Proposal – 2nd Summer 2009

Introduction: The three dimensional volumetric images produced by computed tomography (CT) systems provide an accurate means of locating static targets for diagnosis, treatment, as well as dose verification measurements. For cancers of the thorax and abdomen, however, an assumption of static structures will result in artifact-ridden images because of organ motion due to patient breathing. This investigation will concentrate on cone beam CT (CBCT) and conventional 3D CT.

Both CBCT and conventional CT provide 3D images of patient anatomy, but the difference lies in the means by which the images are acquired and mapped into 3D objects. In conventional CT, the x-ray source projects a fan-shaped beam through the patient to the detector, in effect transversely slicing the patient anatomy with every rotation. The result is a 2D image of a transverse slice of the patient (from anterior to posterior), and after several such rotations, these images can be lined up to create a transverse 3D volume image. In CBCT, however, the x-ray emitted has a cone-shaped beam, so each projection of x-ray to the patient creates a 2D image of patient anatomy oriented in the superior-inferior direction. The result is greater longitudinal coverage with one 360 degree rotation. In one rotation, usually several hundred such projections are obtained and reconstructed to produce a 3D volume image of sagittal, transverse, and coronal views.

In a CBCT system integrated into a linear accelerator (linac), the machinery is extremely heavy and unwieldy, and as such the International Electrotechnical Commission (IEC) mandates that the system move at a maximum of 60 sec per gantry rotation for safety reasons. In terms of a patient's breathing cycle, one gantry rotation will encompass 10 to 20 complete respiratory periods at this speed, a motion which will produce artifacts such as blurring and streaking in CBCT images.

For conventional CT, the source and detector rotation is much faster, resulting in images that in effect "freeze" the patient anatomy at a given time in the breathing cycle. After the application of standard reconstruction algorithms, image distortions such as discontinuities and blurring have been observed and can be attributed to mismatched "stitching" together of images.

Various studies have been undertaken to relieve the problems of respiratory artifacts by using some form of respiratory correlation or four-dimensional (4D) CT and CBCT. The images are acquired simultaneously with a time-axis respiratory profile of the subject, and each projection is correlated into predetermined respiratory phase bins post-acquisition. Standard clinical protocol is to define 10 phase bins per respiratory period, corresponding to end expiration, end inspiration, etc. These techniques have produced quality results, but investigations have focused mostly on maximizing volumetric coherence rather than actually minimizing motion artifacts. A system to minimize motion artifacts would have to be highly adaptive and patient specific, and such technology is further off in the horizon. My study aims to maximize respiratory artifacts so that their origin and nature can be further analyzed and compared between 4D CT and 4D CBCT.

Methods and Materials: The QUASAR respiratory motion phantom will be programmed to mimic irregular respiratory patterns recorded from actual patient data. It consists of a motor to produce programmable sinusoidal motion encased in an acrylic cylinder. The motion produced by the phantom will used to produce longitudinal motion in a custom made acrylic platform on which several acrylic shapes will be placed. The shapes used will be determined by what produces the most prevalent artifacts during sinusoidal longitudinal motion. 4D CBCT and 4D CT images of the longitudinal motion will be acquired using the above mentioned reconstruction algorithms and phase binning techniques.

We will be using a Varian Trilogy Linear Accelerator with on-board imager and real-time position management system (RPM) to acquire the 4D CBCT images. The **** and RPM will be employed to acquire the 4D CT images.

Progress Report: At this time, an acrylic holder is being machined to keep the Quasar phantom and longitudinal motion platform aligned and in unison.

Possible Implications: No other study has been performed on the difference between artifacts produced in 4D CBCT images and those produced in 4D CT images. By maximizing the artifacts, we hope to understand their differences in nature and origin, and perhaps develop phase-binning algorithms unique to each imaging modality, as opposed to a one-size fits all protocol.

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