Abstract

Tomography is the science of cross-sectional imaging of objects. In X-ray computed tomography (CT), the net attenuation of the X-rays as they pass through an object is measured. These measurements, called the projections, are collected at different views, which help to calculate the attenuation coefficient distribution of the object. Use of different geometries for data-collection in tomography results in different reconstruction formulae. The different geometries used in CT are parallel-, fan- and cone-beam geometries, the fastest of which is the cone-beam geometry. Also, cone-beam tomography is the best in the optimized usage of X-rays. This geometry has the added advantages of volumetric reconstruction too.

We have developed two new cone-beam reconstruction algorithms. The first algorithm is developed using a geometric reasoning, which results in a reconstruction algorithm that is faster than the well-known algorithm proposed by Feldkamp, Davis and Kress. In our algorithm, the lengths that each ray intersects in the voxels in its path are calculated. During backprojection, these lengths modulated by a 3D Gaussian function, centered at the voxel center, are used as weight factors. In the second algorithm, cone-beam backprojection is performed along fan-beams which are rotated with respect to the central fan-beam, about the axis of the cone. A reconstruction formula is derived for this configuration. This method has some engineering advantages, owing to the distribution of detectors on a polar grid. For imaging steady objects, a linear array of detector elements is sufficient for data-collection, which needs to be rotated about its center to collect data for a complete cone-beam. Studies were carried out to
incorporate ray-tracing corrections to the cone-beam reconstruction algorithm.

Tomographic imaging of semitransparent objects by illuminating with an optical beam is analogous to X-ray computed tomography. The projection data is the measured phase distortions that the optical beam undergoes when it passes through an object. Such semitransparent objects, which are called phase objects, are weakly absorbing and change only the phase profile of the interrogating optical beam. We experimentally generated a phase object, which is an under-expanded supersonic flow of gaseous nitrogen. The phase distribution, which is the projection data, cannot be directly measured, as the detectors available are intensity sensitive and measure only the amplitude but not the phase. Interferometric methods are one of the indirect means of phase retrieval but are disadvantageous due to the requirement of vibration-free setups. Moreover, designing a robust interferometric setup for tomography, which requires data-collection at different views, is too complex.

Analysis of axial transport of intensity can be used for phase retrieval. In this non-interferometric method, an equation, namely, the transport of intensity equation (TIE), which comes from the continuity equation is used. The TIE is based on the principle that the axial intensity transport is dependent on the shape of the wavefront. The supersonic flow is illuminated with an optical beam and the transmitted intensity is measured. Intensity distributions recorded on two transverse planes are input to the TIE to solve for phase. From the calculated phase distortions, the refractive index distribution (which holds a linear relationship with density) of the object is obtained by using a cone-beam tomographic algorithm.

Another class of non-interferometric methods for phase-retrieval is sensing local slopes of the wavefront. We developed a simple setup which consists of a transparent sheet with random opaque dots imprinted on it. We call this a shadow-mask. When a light beam falls
on the shadow-mask, its shadow is formed along geometric lines of propagation of light. This shadow depends on the shape of the wavefront of the illuminating beam. We record images of shadow of the mask with and without gas flow. The local slopes of the wavefront are calculated by comparing small sub-regions of these images. The wavefront is reconstructed from its slopes and this phase data is fed to the cone-beam tomographic algorithm, to obtain the refractive index distribution (and in turn, the density distribution) of the 3D object.