Abstract

We present a novel polychromatic dual energy computed tomography (CT) method for the detection of objects, particularly explosives, whose chemical properties are assumed to be known with some level of uncertainty. Specifically, we assume that chemical properties of materials are uniquely defined by energy independent Compton scattering and photoelectric absorption coefficients, and particular type of explosives are characterized by an elliptical region in the Compton scatter photodetector coefficient space. The solution, distinct images of Compton scatter and photoelectric absorption coefficients, is obtained via an optimization process where the prior knowledge about the characteristics of explosive objects is imposed as hard constraints. The boundaries of the explosive objects are determined by a level set approach and the background images are represented using a low order basis expansion method. Error in the photoelectric coefficient reconstruction is reduced by employing a regularization which favors a photoelectric absorption image that is structurally similar to the Compton scatter image. A DCOM image of a CT scan of a duffle bag and an artificial image with piecewise constant objects with various shapes and intensities are used as phantoms. Computer simulations show that the algorithm successfully locates the explosive objects if any are present and provides an adequate characterization of background clutter. Therefore the algorithm can be implemented on a real CT scanner.

State of Art

- Dual energy x-ray tomography allows material characterization[1].
- Used for large variety of applications such as:
  - Non-destructive material evaluation
  - Aviation Security
  - Bone densitometry
  - Image based iterative methods are efficient for medical imaging [5]

Research to Reality

- Opportunity to decrease false alarm rate for checked luggage scan for explosive materials
- Image based reconstruction is immune to artifacts such as scatter [2]
- The method can be tested with data from real scanners

Polychromatic CT Formulation

We present a novel polychromatic dual energy computed tomography (CT) method for the detection of objects, particularly explosives, whose chemical properties are assumed to be known with some level of uncertainty. Specifically, we assume that chemical properties of materials are uniquely defined by energy independent Compton scattering and photoelectric absorption coefficients, and particular type of explosives are characterized by an elliptical region in the Compton scatter photodetector coefficient space. The solution, distinct images of Compton scatter and photoelectric absorption coefficients, is obtained via an optimization process where the prior knowledge about the characteristics of explosive objects is imposed as hard constraints. The boundaries of the explosive objects are determined by a level set approach and the background images are represented using a low order basis expansion method. Error in the photoelectric coefficient reconstruction is reduced by employing a regularization which favors a photoelectric absorption image that is structurally similar to the Compton scatter image. A DCOM image of a CT scan of a duffle bag and an artificial image with piecewise constant objects with various shapes and intensities are used as phantoms. Computer simulations show that the algorithm successfully locates the explosive objects if any are present and provides an adequate characterization of background clutter. Therefore the algorithm can be implemented on a real CT scanner.

Reconstruction Algorithm

- Solution via a constrained optimization problem
- Penalized least squares approximation for Poisson log-likelihood [3]

\[ \minimize |\theta| \quad \text{subject to} \quad g_i(p, r) \geq 0, \quad \text{for } i = 1, \ldots, N \]

- First term in \( R(x) \) penalizes oversized objects
- Second is a correlation type metric enforces the structural similarities between two images

Reconstruction Examples

- 4D: white Gaussian noise simulates detector read-out noise
- 150 Projections for 30 uniformly distributed angles between 0° and 180°
- 20x20cm images are discretized into 100x100 pixels
- 4x4 pixel sized background basis functions
- 144 expansion coefficients for the object function
- Comparison with a dual energy filtered back projection method

References: