Pure Translational Tomography – a Non-Rotational Approach for Tomographic Reconstruction

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Abstract. We report the first preliminary simulated experiments of an algebraic iterative tomographic reconstruction algorithm having excellent materials identification accuracy, based on linear stepping scans of 3D objects. The new algorithm, mainly intended for luggage control CT implementation, could substantially reduce the equipment cost, size and the scanning time, offering also good materials identification accuracy.

Introduction

The classical X-Ray Computed Tomography (CT) technique - based on rotational movement around the object - requires many hundreds views or projections for getting a free artefacts tomogram and for identifying materials by attenuation coefficients measurements with good accuracy. Usually, the gantry and the related equipment for X-Ray source and detectors rotation gives the size, complexity and the main cost of an actual CT and limits dramatically the scanning time. All above drawbacks are more critical for the CT application in luggage control (EDS) where we intend to propose the replacement of the rotational-based scanning method with a linear movement scan and to develop a dedicated Pure Translational Tomography algorithm having enough accuracy for applying dual(multi)-energy materials identification technique.

We mention that many well-known reconstruction algorithms, like basic and variants of Laminography and Tomosynthesis for example [1,4], have been developed and tested in non-rotational tomographic scan or in very limited angle scan but, due too large artefacts in tomograms [5], none of the above technique succeeded in being used in high accuracy materials identification algorithms.

1. Scanning method and Iterative Algebraic Algorithm

The method proposed by us is based on simple translational scan of the object on a belt system like in ***Figure 1***, where two variants are presented. The first is using a number of individual linear array detectors, being able to reconstruct the same number of object’s cross-sections tomograms. The second is using a flat panel detector and is capable to reconstruct the full 3D object. For simplifying the algorithm presentation we are describing in following only the 2D case with the scan geometry presented in ***Figure 2***, the 3D case representing a successive application of the 2D algorithm**.** In ***Figure 2*** a matrix that is linear translated in steps parallel with the linear array detector represents the scanned object. At each object's position a set of detectors data is acquired, representing a projection.

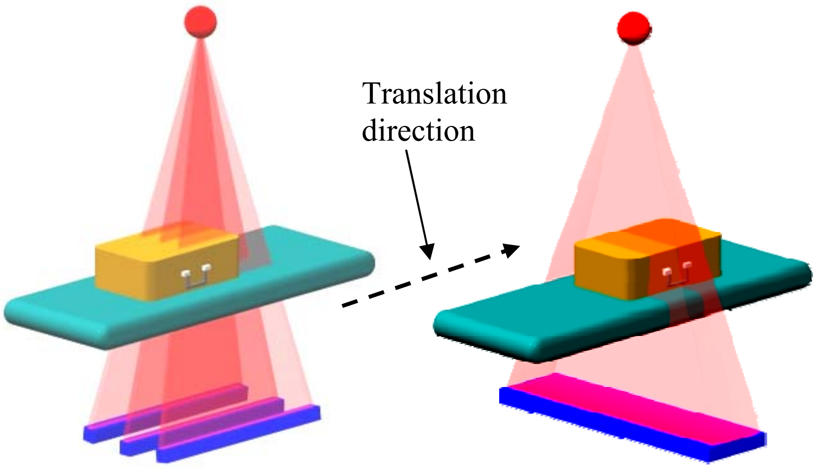


Figure 1. The proposed tomographic translational scan by using a number of individual linear array detectors or a flat panel detector, obtaining after reconstruction 2D slices or full 3D object

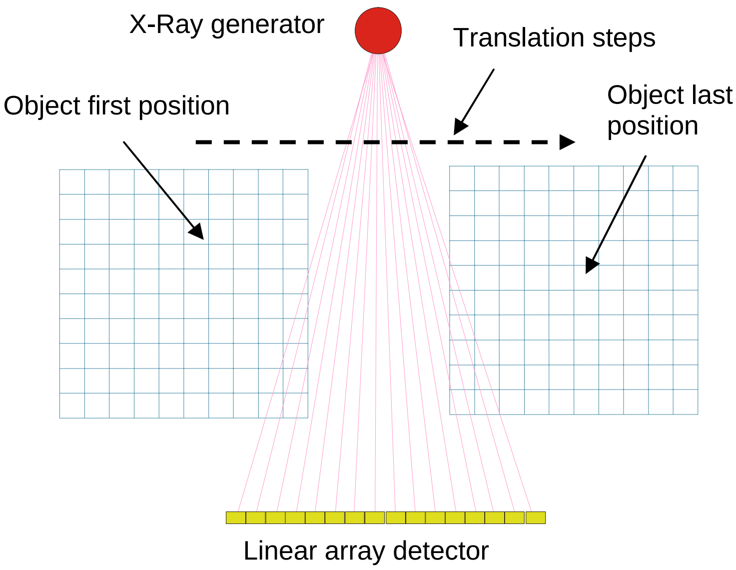


Figure 2. The proposed scan geometry where the object, represented by a matrix, is translated in steps parallel with the linear array detector

The reconstruction algorithm, used in our simulated experiments, is based on a classical iterative ART method, like described in [6]. It is applied for each ray of each projection (acquired for successive object position) and successively modifies each pixel value belonging to each ray, as presented in the following formula:

$$\mu_{ij}^{new} = \mu_{ij}^{old} + \lambda(k) \times [p^l - \sum_{i,j}^{N} (a_{ij}^l \times \mu_{ij}^{old})] \times \frac{a_{ij}^l \times \mu_{ij}^{old}}{\sum_{i,j}^{N} (a_{ij}^l \times \mu_{ij}^{old})} \qquad (1)$$

where symbols are:

μ_{ij}^{new} - the actual or modified/corrected attenuation coefficient value of pixel *i,j*;

μ_{ij}^{old} - the old iteration attenuation coefficient value of pixel *i,j*;

$\lambda(k)$ - the dumping factor correlated with the iteration number *k;*

a_{ij}^{l} - the attenuation length of pixel *i,j* in the ray *l* for a given projection;

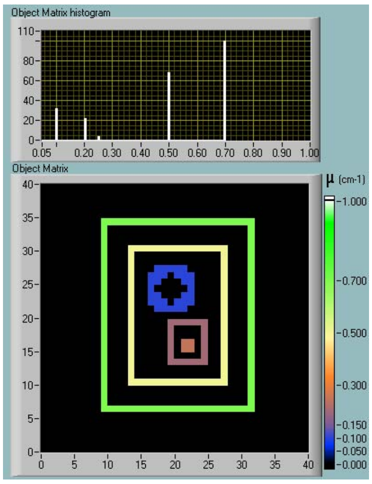
p^{l} - the data acquired in the detector number *l* at a given projection

$\sum_{i,j}^{N}(a_{ij}^{l} \times \mu_{ij}^{old})$ - the total attenuation of ray *l* for a given projection.

The a_{ij}^{l} values are pre-computed by using a complex ray-tracing algorithm for each ray, from each projection and all data are stored in a 4D matrix for being used in tomogram reconstruction based on formula (1).

2 Simulation and experiments

The entire work of the scanned objects simulation, the generation of reconstruction geometry and of scanned object data acquisition, the implementation of the reconstruction algorithm based on equation (1) and also the data analysis algorithms were implemented using *LabView®* graphical language from *National Instruments Company.*



Taking into account that the scanning was made along only one direction, we build a simulated object (**Figure 3**) with many pixels line parallel with the direction of scan, knowing that this kind of lines are most difficult to be reconstructed from projection normal to lines. Also, for emphasizing the materials identification accuracy, different attenuation coefficients materials have been used in simulated object construction and the histogram of the attenuation coefficients is presented above each tomogram.

Figure 3. The simulated object made from five different materials and its histogram.

Based on the type of geometry described in **Figure 2,** the simulation was made having the following parameters:

Object matrix size: 40x40 with 4 mm pixel size
Linear array detector: 800 detectors x 0.8 mm width
Translation steps: 50 steps x 6.3 mm/step
X-Ray source-Linear detector distance: 470 mm
Radiation noise added: ± 2 %
Radiation scattering ratio: 5 %
Number of Projections (steps)**:** 50
Simulated object contains five types of attenuation coefficients materials: 0.1 cm^{-1}, 0.20 cm^{-1}, 0.25 cm^{-1} (four pixels only), 0.5 cm^{-1} and 0.7 cm^{-1}

The projections data were generated based on a ray-tracing algorithm and, for simulating the real condition, a statistical noise of maximum ± 2 % and a 5 % scattering contribution of neighbors' rays were added.

The tomographic reconstruction result is presented in **Figure 4,** where the 1st, 5th, 10th, 15th, 25th and 34th iteration tomogram with its histogram are presented. The one iteration computation time was about 6 seconds, with program written in LabView® running on PIV 2GHz PC machine.

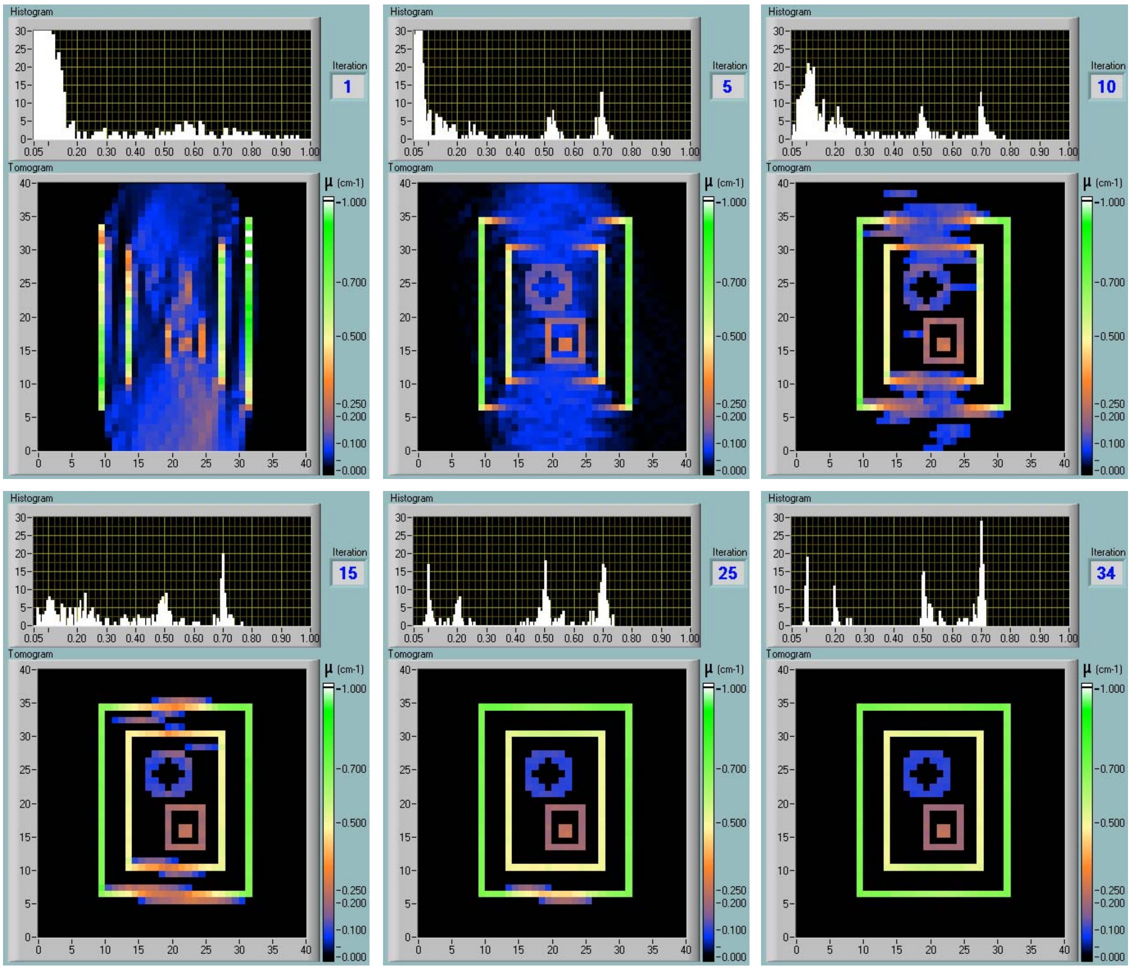


Figure 4. The reconstructed tomograms of simulated objects and histograms at 2nd, 5th, 10th, 15th, 25th and 34th iteration

We should notice that the new algorithm succeed to reconstruct the vertical lines within first few iterations, but for the horizontal lines clear details reveals only after 15th iteration and the entire reconstruction process was almost finished after 30 iterations. The histogram reveals good materials peaks after 25 iterations and after the last iteration the peaks could be clearly distinguished and fitted. The differences in materials attenuation coefficients values were within ±0.2 % from simulated object values.

3 Conclusion

The algorithm and the simulations presented are very encouraging and the new technique seem to be a very promising algorithm for translational tomography of the objects, with main application in CT for luggage control where materials identification accuracy is a must. The algorithm, which initially improperly was called *Pure Translational Tomography*, could be now applied at any tomographic reconstruction, for any projection regarding the object, at any trajectories or angle and could give lees artefacts tomograms and better constituent's histogram accuracy than classical analytical algorithms. Theoretically, due to the specific algorithm used in evaluation of the rays, could be possible to reduce the effect of X-Ray source focal spot size by describing it like a multi-point source. Also, because the reconstruction algorithm is based on individual pixel contribution on each ray, bigger detector size could be used for reconstructing matrix with smaller pixel size, increasing in this way the data acquisition signal to noise ratio. Both this new potential features will be further tested by simulation. Of course, the reconstruction time remains the main issue of our iterative algorithm but, taking into account that a factor of hundreds times faster could be easily reached only by writing the algorithm using faster code and a cluster of powerful computer could be used for computation, the reconstruction time could be decreased easily at an acceptable value. A laboratory experiment is already planed and soon first results will be presented.

References

[1] U. Ewert, J. Robbel, C.Bellon, A. Schumm, and C. Nockemann, Digital laminography, International Symposium on Computerized Tomography for Industrial Applications, DGZfP Proceedings (1994) 148

[2] J. Zhou, M. Maisl, H. Reiter, and W. Arnold, Computed Laminography for Materials Testing, Applied Physics Letters 68 (1996) 3500

[3]. Kolitsi, Z.; Panayiotakis, G; Anastassopoulos, V.; Skodras, A.; Pallikarakis, N. A multiple projection method for digital tomosynthesis. Med. Phys. 19(4): 1045-1050; 1992.

[4] S. Gondrom and S. Schroper, Digital computed Laminography and tomosynthesis, Computerized Tomography for Industrial Applications and Image Processing in radiology, DGZfp Proceedings BB 67-CD Paper11

[5] Bernard & Alan Hume, Reviewing Laminography False Calls; David Dage Precision Industries, d.bernard@dage-group.com

[6] G.T. Herman, "Image reconstruction from projections", Real-Time Imaging, 1995, 1, pp. 3-18.