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***Abstract*— CT scanners are deployed world-wide to detect explosives in checked and carry-on baggage. Though very similar to single- and dual-energy multi-slice CT scanners used today in medical imaging, some recently developed explosives detection scanners employ multiple sources and detector arrays to eliminate mechanical rotation of a gantry, photon counting detectors for spectral imaging, and limited number of views to reduce cost. For each bag scanned, the resulting reconstructed images are first processed by automated threat recognition algorithms to screen for explosives and other threats. Human operators review the images only when these automated algorithms report the presence of possible threats. The US Department of Homeland Security (DHS) has requirements for future scanners that include dealing with a larger number of threats, higher probability of detection, lower false alarm rates and lower operating costs. One tactic that DHS is pursuing to achieve these requirements is to augment the capabilities of the established security vendors with third-party algorithm developers. A third-party in this context refers to academics and companies other than the established vendors. DHS is particularly interested in exploring the model that has been used very successfully by the medical imaging industry, in which university researchers develop algorithms that are eventually deployed in commercial medical imaging equipment. The purpose of this paper is to discuss opportunities for third-parties to develop advanced reconstruction and threat detection algorithms.**

***Index Terms*—Explosive, detection, Homeland Security**

I. INTRODUCTION

Scanners based on CT technology are deployed at airports to detect objects concealed in checked luggage. The term explosive detection system (EDS) is used in this paper to refer to this CT-based equipment. EDS scanners are known to have a high false alarm rate leading to high labor costs to resolve the false alarms.

DHS has requirements for future EDS equipment that include increased probability of detection (PD) and decreased probability of false alarm (PFA) for a larger set of objects and with reduced minimum masses. The reduced minimum mass requirement is due in part for the desire to deploy EDS at the check-point. The larger set of objects includes certain types of homemade explosives. There are indications that these requirements for future EDS equipment may be difficult to achieve with the technologies presently deployed in the field.

In order to resolve these issues, DHS has adopted the strategy of augmenting the capabilities and capacities of the incumbent vendors of EDS equipment with the involvement of third parties. Third parties are defined as researchers from academia and industry other than the incumbent vendors. The goal is for third parties to develop technologies that could eventually be deployed by system integrators such as the incumbent vendors.

DHS tasked Northeastern University to conduct a series of workshops to identify which topics could be addressed by third-parties. The workshops mainly dealt with algorithms, but they also dealt with improved sensor hardware and fused systems. These workshops have been entitled Advanced Development for Security Applications (ADSA). The major findings of the ADSA workshops, as related to CT-based EDS, have been that third parties can play a role in the development of advanced algorithms and can assess the impact of hardware that leads to improved image quality [1-4].

The purpose of this paper is to discuss opportunities for third-parties to develop advanced reconstruction algorithms for CT scanners used to detect explosives.

II. PROBLEM STATEMENT

The performance of an EDS is affected by objects that are split or merged during the segmentation step of automated threat recognition. The splitting and merging are caused by CT artifacts such as image blurring, partial volume, streaks, low-frequency shading, noise, rings and bands. The automated threat recognition algorithm also generates features of objects such as mass, density, volume and effective atomic number. The artifacts degrade the measurements of these features.

III. OPPORTUNITIES

The following opportunities have been identified for advanced algorithms for CT-based EDS equipment to reduce the effects of artifacts on automated threat recognition algorithm.

Iterative reconstruction techniques (IRT) are well-suited for security applications because the threats (explosives) consist of multiple voxels. Image constraints, such as a smoothness function, are particularly applicable to homogeneous threats. An IRT may have to be applied to the raw data instead of the corrected data because of the presence of metal. Compressed sensing, model based, total variation and simultaneous image reconstruction may be promising. High-resolution targeted reconstructions may be necessary if computational times are too long for the complete scan field-of-view.

IRT may also be useful to improve the performance of dual-energy and spectral imaging.

Sinogram processing may be useful to reduce or eliminate streak, cupping and dishing artifacts. These artifacts are caused in part due a polychromatic x-ray source, scatter and electronic noise.

Localized beam hardening correction may be useful because the diverse nature of objects (threats and non-threats) present in luggage.

Image processing may yield the same or similar benefits as IRT. The equivalent methods used in medical and nondestructive evaluation imaging should be evaluated on scans of luggage.

Hybrid reconstructions methods (1-2 iterations plus filtered back-projection) may be promising as a compromise to IRT.

Reconstruction using truncated projections should be considered, especially if leading to high-resolution scanning of targeted regions of interest.

Image quality could be optimized for automated threat recognition algorithms.

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