Detection with Spectral X-Ray Detectors and the Complimentary Method of X-Ray Diffraction

Ed Franco, Jonathan Kerner, Winston Chow, Ed Morton, and the team from MultiX

Presented at the ALERT ADSA Workshop 09: New Methods for Explosive Detection for Aviation Security, October 22-23, 2013 Northeastern University, Boston, MA
Conclusions

• These Approaches Show Promise for Improving Performance Based on Laboratory Results
  - Multi-energy imaging improves material discrimination and segmentation
  - Coherent x-ray scatter provides material specific signatures

• Additional R&D Required for Aviation Screening
  - Multi-energy imaging and scatter are part of an evolving concept for material identification
  - Development and testing of systems under practical CONOPS
  - Screening for HMEs remains a challenging application
  - Research partnerships may accelerate development
The Challenge

- Dual-Energy Systems are Used to Screen for Aviation Threats
  - Achieves high PD with an operationally acceptable PFA
  - Commercial and military explosives are generally well separated from benign items in $\rho$-Zeff space

- Screening for Home Made Explosives (HMEs)
  - HMEs are variable due the way they are produced (raw materials, impurities, and manufacturing processes) and chemical effects (aging)
  - Significant overlap with benign items in $\rho$-Zeff space
Rapiscan Investigating Multiple Approaches to Improve Detection and Reduce False Alarms

- Multi-Energy Imaging
  - Better measurement of $\rho$ and $\text{Zeff}$
- Coherent X-Ray Scatter
  - Provides orthogonal signature related to atomic structure
- Other Approaches
  - Tomography
  - Phase contrast
  - Compressive sensing
Dual-Energy (DE) vs. Multi-Energy (ME) Imaging

- DE uses two broad overlapping LE and HE bands
- ME uses the entire transmitted spectrum

Calculated absorption in DE and ME detectors

DE (top) and ME (bottom) detector modules
DE vs ME Accuracy

Result of clutter is enlarged "cloud" of uncertainty on absolute value
Effect of Clutter in Bags
Multi-Energy Imaging

• Benefits
  - Improved material discrimination due to increased accuracy and precision in the measurement of Zeff and density
  - Improved segmentation due to improved resolution and image quality

• Shows promise for improved PD and PFA

• BUT clutter is a problem in quantitative imaging …

• Future efforts are focused on cargo, checkpoint, and hold-baggage applications
Rapiscan has over 10 years experience with XRD and Coherent X-Ray Scatter

• University Collaborations

• Bulk Explosives
  - Rapiscan XRD1000 system used XRD for alarm clearing

• Home-Made Explosives
  - Proprietary technology

XRD1000 Baggage Inspection System
Combined dual-view, dual-energy imaging with integrated XRD subsystem
Pencil Beam Coherent X-ray Scatter Geometry

- Pencil beam geometry is very simple
  - However not very efficient
  - Probes only a single point

- Rapiscan is investigating more efficient geometries

CZT detectors | Sample | X-ray source
---|---|---
160 kV, 5 mA Tungsten anode

Scatter angle ~ 5 degrees
Produces Unique Material-Dependent Transmission and Scatter Signatures

- Bulk and HME explosives
- Stream-of-passenger items

**Raw Transmission Spectra**

**Raw Coherent X-ray Scatter Spectra**
Processed and Normalized Scatter Signature

- Scatter signatures of threat materials distinguishable from benign materials (see red ovals)
- Can be used in automated classification algorithms
Conclusions

- These Approaches Show Promise for Improving Performance Based on Laboratory Results
  - Multi-energy imaging improves material discrimination and segmentation
  - Coherent x-ray scatter provides material specific signatures

- Additional R&D Required for Aviation Screening
  - Multi-energy imaging and scatter are part of an evolving concept for material identification
  - Development and testing of systems under practical CONOPS
  - Screening for HMEs remains a challenging application
  - Research partnerships may accelerate development