Reconstruction Project: Project Overview

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Project Objectives

- Develop improved reconstruction algorithms, which may be deployed in the future, for CT-based explosive detection systems using scans of objects of interest on medical CT scanners and using simulated data and standardized phantoms
- Putting a database of raw data of scans of bags and associated scanner information into the public domain
- Purpose of this meeting is to see the results of this project

Conclusions

- Nine research groups developed reconstruction algorithms for single- and dual-energy volumetric CT scans of bags
- Quantitative scoring metrics as surrogate for new, tuned ATRs and taking DHS/TSL certification test
  - New reconstruction algorithms are visually and quantitatively better than images using filtered back projection (FBP)
- Public domain set of projections (raw data) and scanner characterizations for third-parties to develop reconstruction algorithms
- Computer simulated data and standardized baggage phantoms to allow algorithm comparisons and lower-cost development of scanners
- Potential outcomes
  - Algorithms transition to fielded EDS
  - Researchers continue working on algorithms with TSA, ALERT and vendors
  - People trained to work in field

ADSA – Workshop Format

- Ask questions in real time
- Do not hold back – but play nice
  - Learning process for all participants
- Interrupt speakers
  - Test now!
- Speakers expect this format
- Agenda allocated time for questions
- Review will end at 5:30 PM

DHS Goals

- Vendors doing an excellent job
- But, need
  - Increase probability of detection (PD)
  - Decreased probability of false alarm (PFA)
  - Detect more threats including wide-variation of home-made explosives (HMEs)
  - Reduced mass
  - Reduced labor costs
    - Eliminate human in the loop if possible
  - New algorithm ideas
  - New people

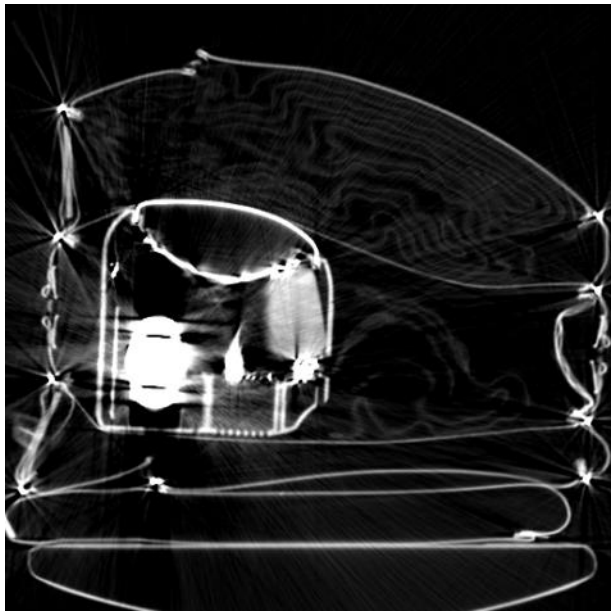
DHS Tactics

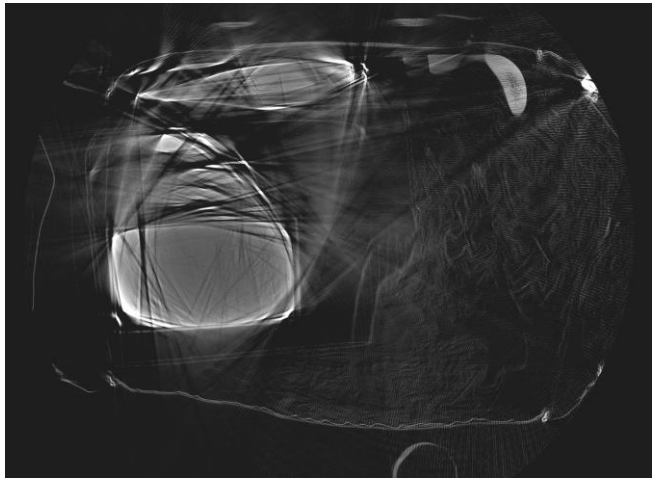
- Augment abilities of vendors with 3rd parties
  - Academia
  - National labs
  - Industry other than the vendors
- Create centers of excellence (COE) at universities
- Hold workshops to educate 3rd parties and discuss issues with involvement of 3rd parties
  - Algorithm Development for Security Applications (ADSA)

ADSA - Recommendations

- ADSA01 Recommendations
  - Organize research projects (grant challenges)
  - Segmentation first – easiest task
  - Reconstruction second
    - Difficult to get projection data and parameters
    - Difficult to assess results
- ADSA04 and ADSA07 refined reconstruction projects

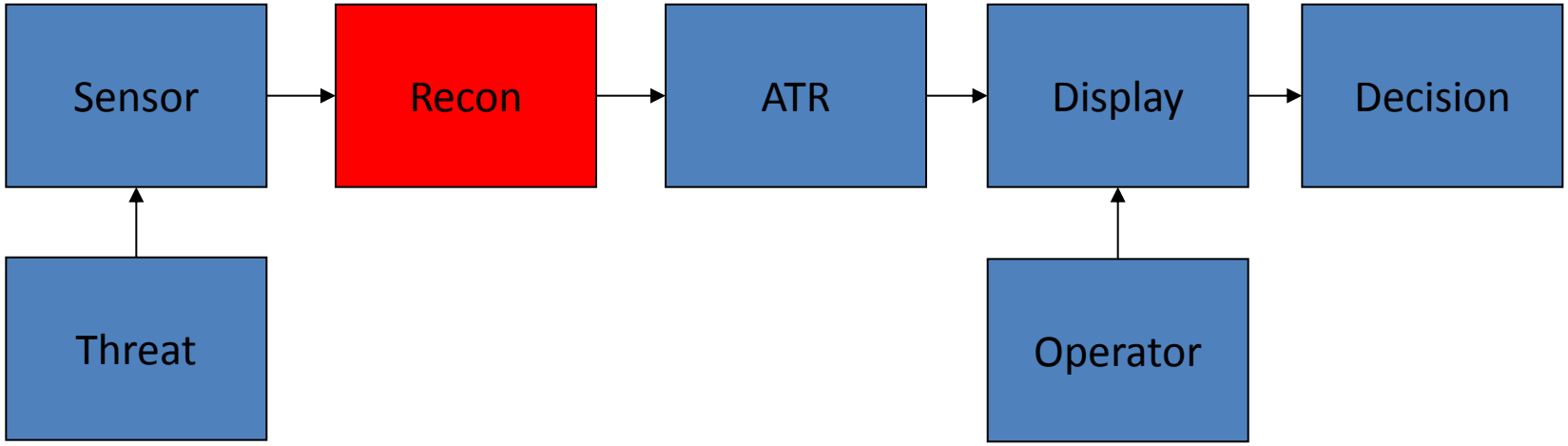
Typical Image Quality



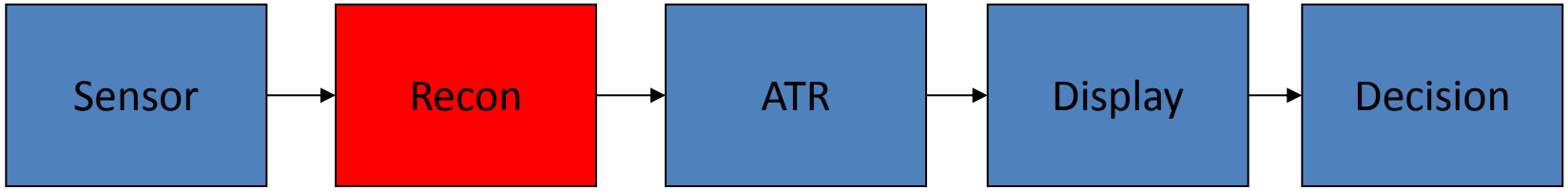


- Artifact types
  - Shading
  - Streaks
  - Noise
  - Blurring
  - Rings
- Artifacts lead to
  - Merging of objects
  - Splitting of objects
  - Imprecise density, volume, mass, shape

EDS Diagram

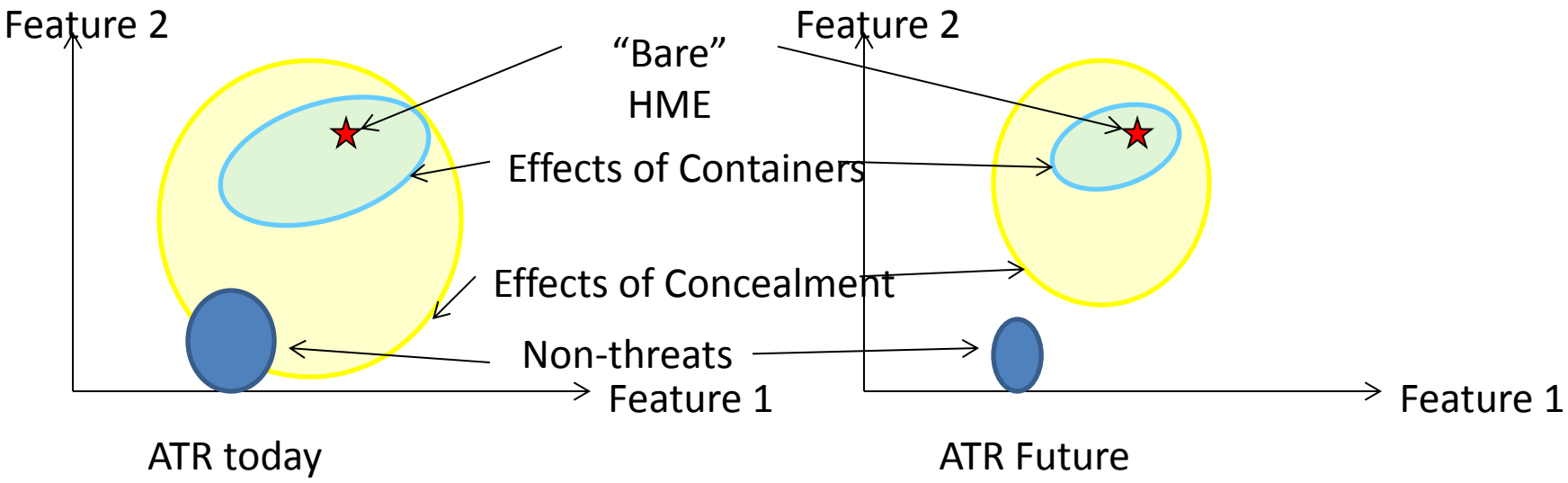


Difficult to Assess Improvement



- ATRs are tuned (matched filter) to image quality (IQ)
- Improved IQ + extant ATR could degrade detection performance
- Developing ATRs and testing at TSL out of scope
  - Testing may not be statistically significant (ADSA08 final report)
- Surrogate metrics required
  - Area of research – as big as recon development itself
  - Based on images, not on detection performance

Reduce Cloud Sizes



Features should be pixel-based and based on segmentation and/or region growing. Pixel-based alone may admit low-pass filtering to reduce artifacts.

Reconstruction Algorithms

- Iterative, algebraic. statistical, model-based
- Filtered back-projection (FBP)
  - FBP is more than what's described in Kak & Slaney
- Pre-processing – sinogram processing, metal artifact removal
- Post-processing – streak removal
- Dual energy – decomposition and integrated reconstruction

Objects of Interest

- Water
- Saline
- Rubber sheets
- Glass beads (to assess texture)

Databases

- Packed suitcases with normal objects
- Scan on medical CT scanner
  - ~100 scans
- Outline objects using semi-automated method
  - Denoted ground truth data
- Scanner characterization (meta-data)

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Simulations

- Goals
  - Reduce dependency on using scanner
  - Develop common set of phantoms for comparing algorithms (ForBild)
- Deliverables
  - Phantom and content (non-OOIs) descriptions
  - Virtual packing software
  - Simulation code and users manual
- Simulate: Imatron scanner including: finite apertures, quantum and electronic noise, beam hardening, scatter, etc.
- All material in the public domain

Researchers

- Iterative reconstruction
  - Jens Gregor, University of Tennessee
  - Synho Do, Massachusetts General Hospital
  - Charlie Bouman, Ken Sauer, Pengchong Jin, Purdue/Notre Dame
  - Jeff Kallman, Harry Martz, LLNL
- FBP, sinogram processing, metal artifact removal
  - Frederic Noo, Larry Zheng, Dominic Heuscher University of Utah
  - Patrick La Riviere, Phillip Vargas,University of Chicago
  - Seemeen Karimi, University of California, San Diego
- Dual/Multi Energy Reconstruction and Decomposition
  - Limor Martin, Clem Karl, Boston University
  - Brian Tracy, Eric Miller, Tufts University
- Metrics
  - David Wiley, Deb Gosh, Stratovan
- Simulations
  - Taly Gilat-Schmidt, Marquette University

Support Tasks

- Scanning
  - Doug Boyd, Sam Song, Telesecurity Sciences
- Third-party FBP
  - Patrick La Riviere, Phillip Vargas,University of Chicago

ProjectTeam

- Program and technical management
  - Michael Silevitch, John Beaty, ALERT
  - David Castanon, Boston University
- Subject matter experts (mentors)
  - Carl Crawford, Csuptwo
  - Clem Karl, Boston University
  - Harry Martz, LLNL

Reminders

- Meeting and results in public domain.
  - No classified or SSI material
  - Minutes will redacted if necessary
- Out of scope
  - Computational expense
- Fill out questionnaire on survey-monkey
  - www.surveymonkey.com/s/ProgramReviewSurvey

Acknowledgements

- Laura Parker, DHS, funding
- Vendor feedback
  - L-3, Analogic, Morpho Detection, Surescan, Rapiscan
- ALERT staff
  - Melanie Smith(**), Teri Incampo, Seda Gokoglu, Kristin Hicks, Can Yegen, Deanna Beirne, Anne Magrath
- Jeffrey Kallman, Steve Azevedo, LLNL, technical support

Special Acknowledgement

- Limor Martin, Boston University
  - Validation of raw data
  - Tracking down bugs
    - Most bugs due to collecting dual energy data on a single energy scanner
  - Offline (xrec) reconstruction
  - Organizing project FTP site
  - Updating documentation
  - Selecting slices of interest

Super Special Acknowledgements

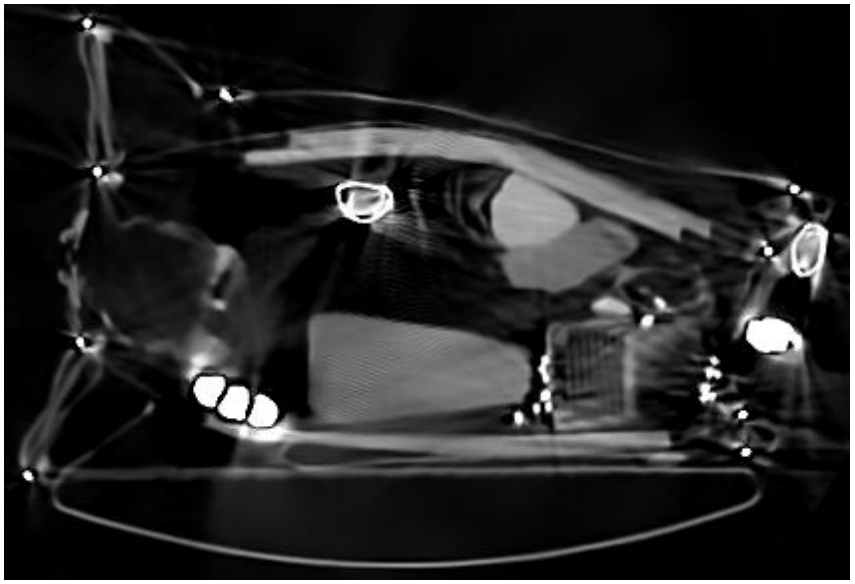
- The reconstruction initiative would not have been a success without the research groups. The success of this project is due 99.99% to their contributions. We extend our heartfelt thanks to them for their participation and working the project team to fix issues when they became evident.

Indemnification

- All problems, issues and bugs are the responsibility of Carl Crawford, Clem Karl and Harry Martz, not the researchers and support staff

Object Philosophy Issue

- Scanned stacks of N rubber sheets
  - Is this one object or N separate objects?
- Area recovery for sheets is inaccurate for this reason



Success

- Develop improved reconstruction algorithms
- Define improved!
- Increased involvement of third parties (i.e., not incumbent vendors)
- Researchers
  - Receiving follow-on funding from government and vendors
  - Publishing, presenting, patenting
- It takes a village to improve national security
  - Create RSNA equivalent for security
- Make DHS/TSA happy!
- Project tools (projections, images) into public domain
- Transitioning algorithms to commercial products