Material Discrimination Using Multi-Energy X-Ray Computed Tomography for Explosives Detection

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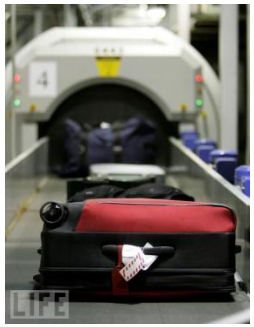
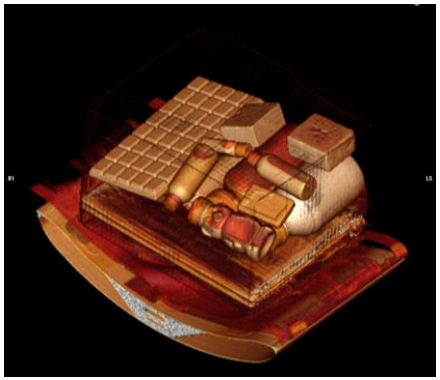
Project scope

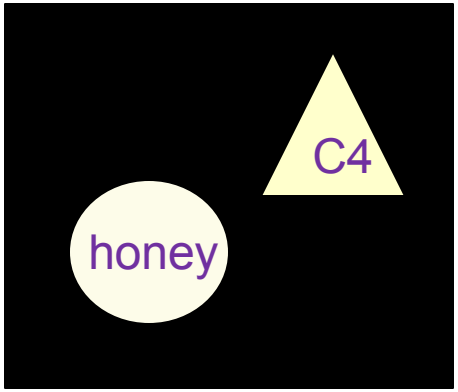


- Motivation: reliable detection of explosives in luggage
- X-ray Computed Tomography (CT) allows us to look "inside" things
- ***Multi-Energy CT (MECT)*** provides additional information about the materials
- Our focus:

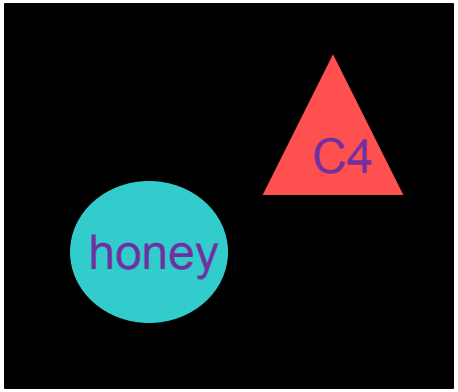
Understanding the information available in MECT and developing optimal methods for material discrimination

real CT scan





conventional



multi energy

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Multi-Energy CT (MECT)

- Research driven mostly by medical imaging
  - Small set of materials (tissue, bone, etc.)
- Security domain – more complicated
  - Anything can go in a suitcase
- Fundamental performance limits for explosives detection still not understood
- Existing commercial systems:
  - Medical:
    - Siemens SOMATOM Definition (bottom figure)
    - Philips Brilliance-64
    - GE Lightspeed
  - Security:
    - Reveal CT-80 (top figure)

Security

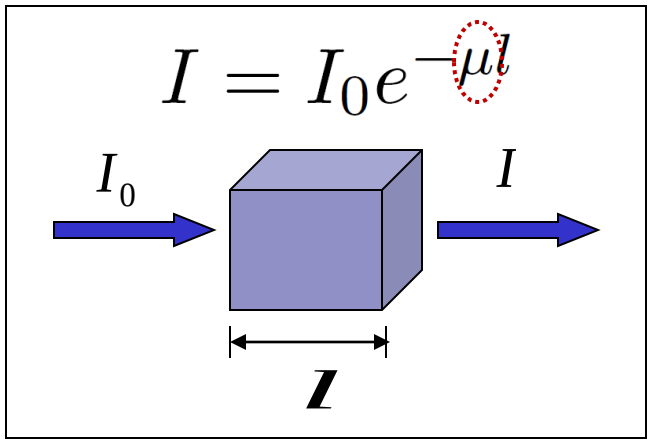
[http://www.revealimaging.com/products.aspx]

Medical

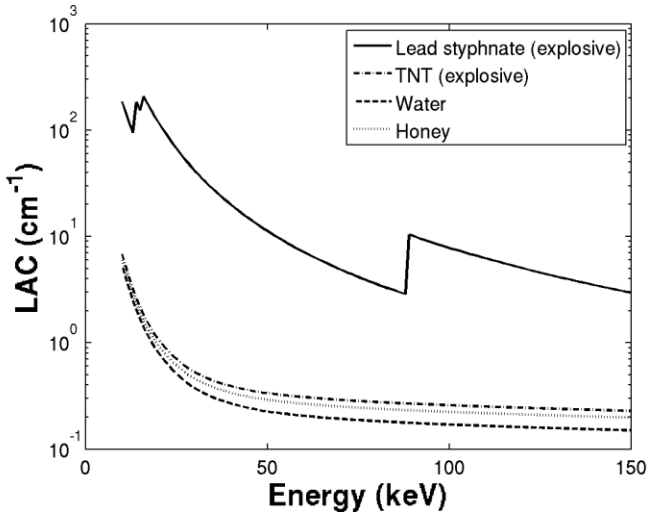
[http://www.medical.siemens.com/]

Materials and X-rays: The LAC

- X-ray interaction with materials captured by the ***Linear Attenuation Coefficient (LAC)***
- Function of X-ray energy
- Material "signature"
- MECT measurements contain LAC info.



Beer's law

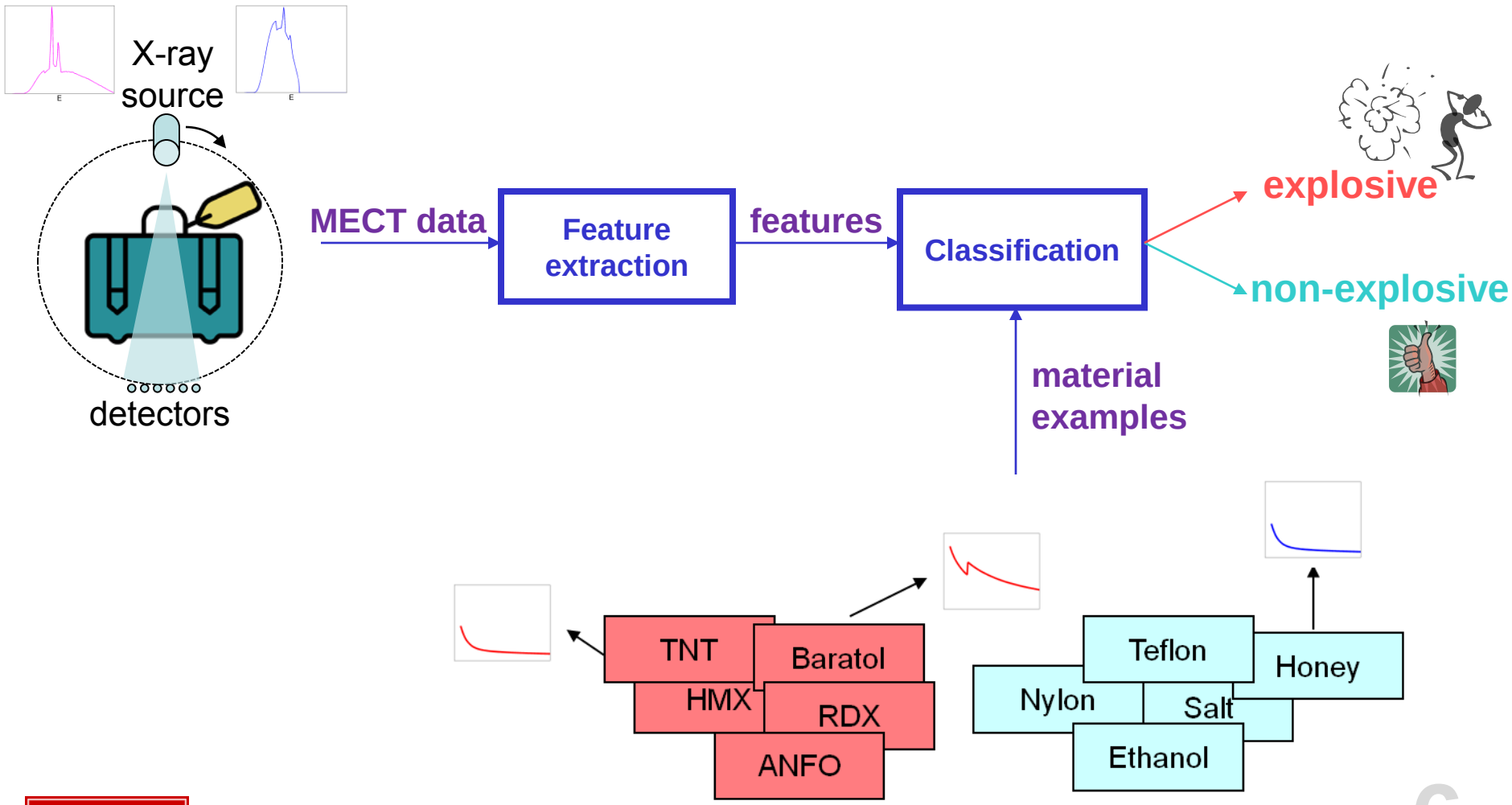


Research agenda

- Broaden understanding of information available in material attenuation curves
  - Fundamental material separability
- Optimize information extraction from curves
  - Optimal feature choice and dimensionality
- Design MECT systems that exploit the optimal discriminating information

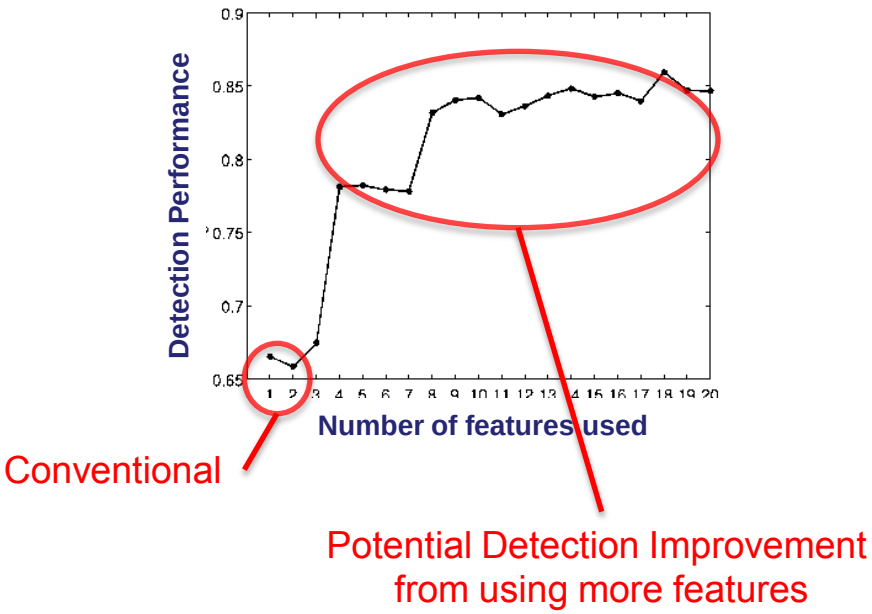
Our tools: principled signal processing and machine learning methods

Machine-learning perspective

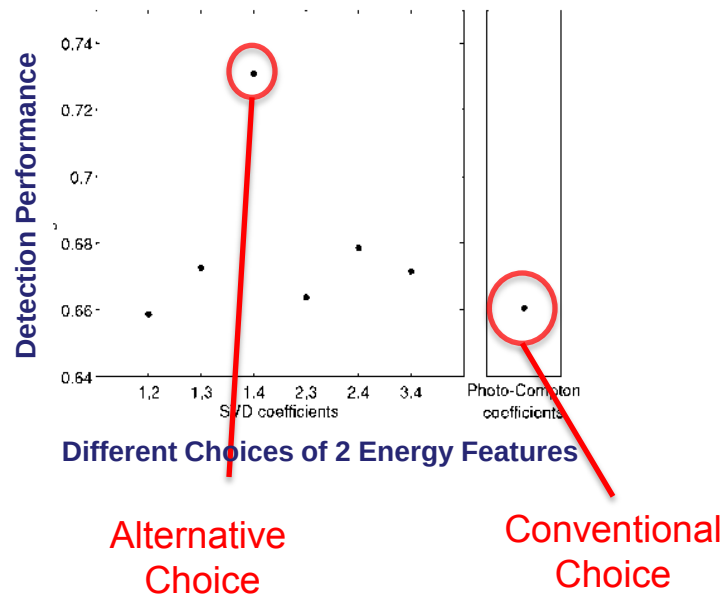


Results #1: feature choice and dimensionality

More features may improve detection



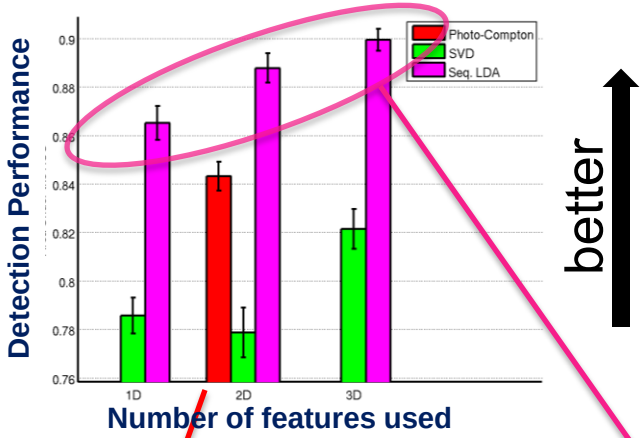
Better features may improve detection



More/different features are better!

Results #2: adaptive features

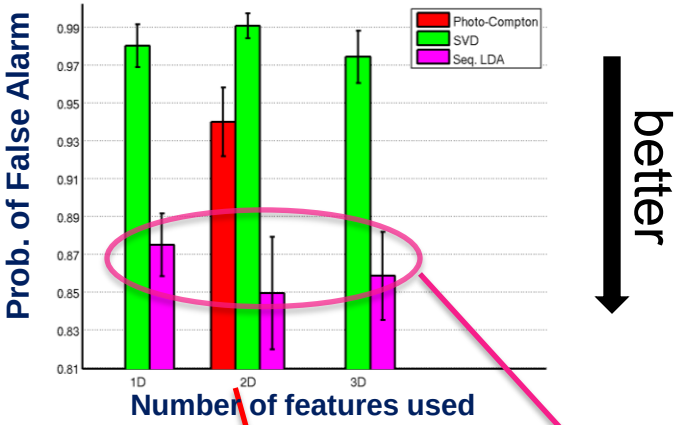
Adaptively learned features have best detection for any number of features



Conventional Choice (fixed photo-Compton)

Learned Features give best detection

Adaptively learned features have fewer false alarms



Conventional Choice (fixed photo-Compton)

Learned features have fewer FA

A single adaptive feature is better than the two conventional features!

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Summary

Impact:

- Understand fundamental limits of MECT performance
- Increase detection of challenging explosives
- Reduce false alarms ➔ increase throughput

Future work:

- Optimal feature identification for MECT
- Incorporate more complete tomographic sensing model

Publications

- Eger, L., Do, S., Ishwar, P., Karl, W., and Pien, H., “A learning-based approach to explosives detection using multi-energy X-ray computed tomography,” Proc. 2011 IEEE Int'l Conf. on Acoustics, Speech, and Signal Processing, Prague, Czech Republic, May 22-27, 2011.

- Eger, L., Ishwar, P., Karl, W., and Pien, H., “Classification-aware dimensionality reduction methods for explosives detection using multi-energy X-ray computed tomography,” in Computational Imaging, C. A. Bouman, I. Pollak, P. J. Wolfe, editors, Proc. SPIE, Vol. 7873, SPIE, San Francisco, CA, January 23-27, 2010.

- Eger, L., Do, S., Ishwar, P., Karl, W., and Pien, H., “A Learning-based method for explosives detection from multi-energy X-ray computed tomography measurements,” CenSSIS RICC, Oct 2010.

- Eger, L., Do, S., Karl, W., and Pien, H., “Implementation of an image-based dual-energy method for explosives detection on real CT data,” CenSSIS RICC, Oct 2009.