SAND2015-1585C

Sandia National Laboratories

The University of Arizona

Information Barriers for Imaging

Christopher J. MacGahan[1], Matthew A. Kupinski[1],
Nathan R. Hilton[2], William C. Johnson[2], **Erik M. Brubaker**[2]
[1]College of Optical Sciences, University of Arizona; [2]Sandia National Laboratories, Livermore CA

PL14-InfoBarrierimg-PD2Nb
Ken Jarman, Tim White (PNNL)

Pacific Northwest National Laboratory
Proudly Operated by Battelle Since 1965

Project Overview/Goals

For this project we leverage advanced inference methods developed for medical and adaptive imaging to address arms-control applications. We seek a method to acquire and analyze imaging data of declared treaty-accountable items without creating an image of those objects or otherwise storing or revealing any classified information. Such a method would avoid the use of traditional information barriers.

The medical tasks of detecting, locating, and classifying the radiation signatures from a medical patient are adaptable to similar treaty-verification tasks. Task-based analysis approaches have the following advantages:

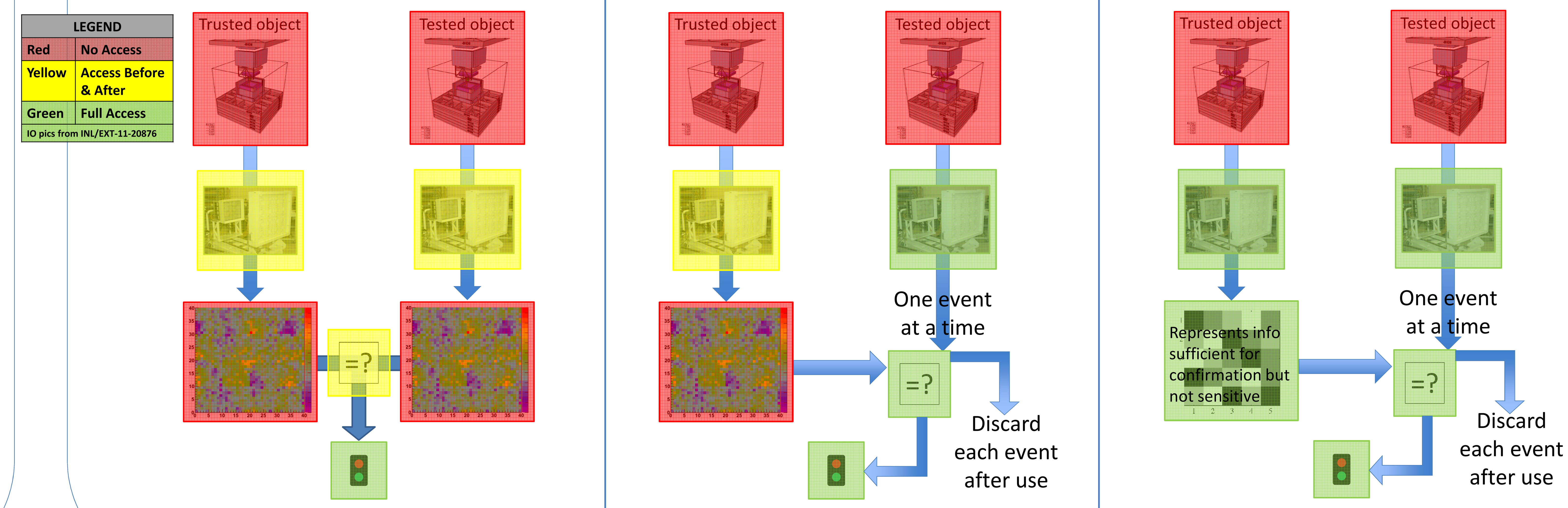
- Based on experience with medical applications, we should achieve superior performance by use of raw image data instead of reconstructed images.
- Data from individual radiation-detection events can be processed as they are measured (list mode), removing the need to store those data for future analysis.
- Processed information cannot be analyzed to recreate the original event data or to extract spectroscopic or geometric information about the object being measured.

The analysis algorithm used to process the list-mode data may itself contain sensitive information (e.g. a high-resolution template of the treaty item). Different algorithms, or "observers", will manifest a tradeoff between sensitivity of the information required and confidence in the verification result.

We are working to demonstrate the concepts described above, using simulations and experimental data from passive radiation imagers, such as the ORNL/SNL neutron coded aperture imager, and radiation sources such as the INL inspection objects.

Protecting sensitive information without a traditional information barrier

"Traditional" approach | *List-mode approach* | *List mode + acceptable observer*



Technical progress, results, and plans

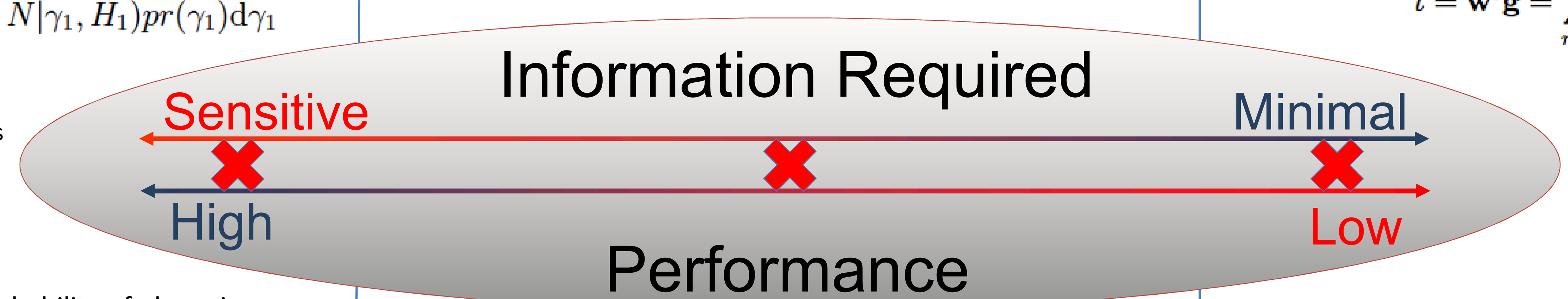
Ideal Observer (Binary Classification)

Theory

The ideal observer performs binary classification tasks. It thresholds the likelihood ratio of observing data (A_n, N) given two different source hypothesis.

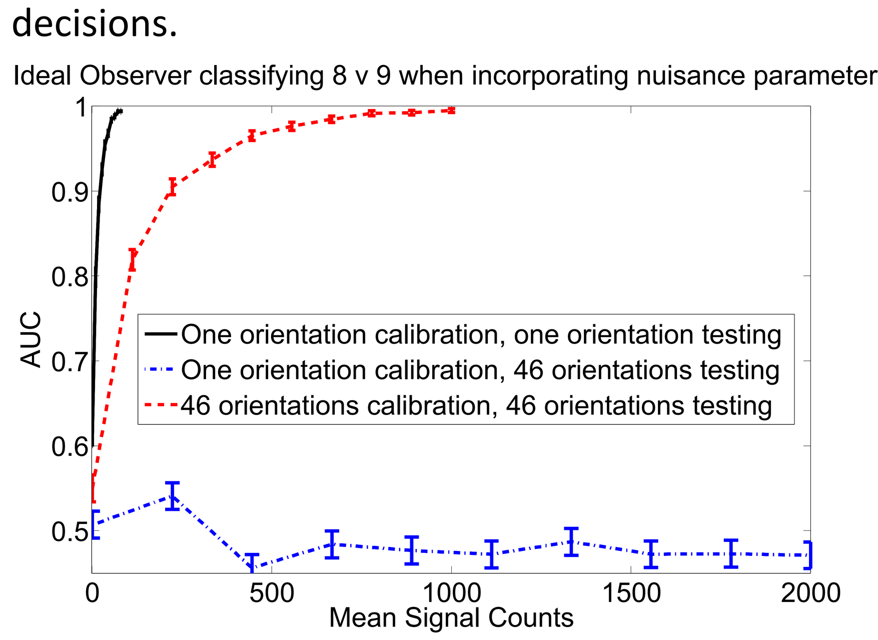
$$\Lambda(\{A_n\}, N) = \frac{\int pr(\{A_n\}, N|\gamma_2, H_2)pr(\gamma_2)\mathrm{d}\gamma_2}{\int pr(\{A_n\}, N|\gamma_1, H_1)pr(\gamma_1)\mathrm{d}\gamma_1}$$

A_n is the list-mode data for event n
N is the total number of detected events
γ is a set of nuisance parameters (e.g. location, orientation)



Information Required

Calibration data is used to find the probability of observing a detected particle in each bin. Data for two sources is required to make decisions.



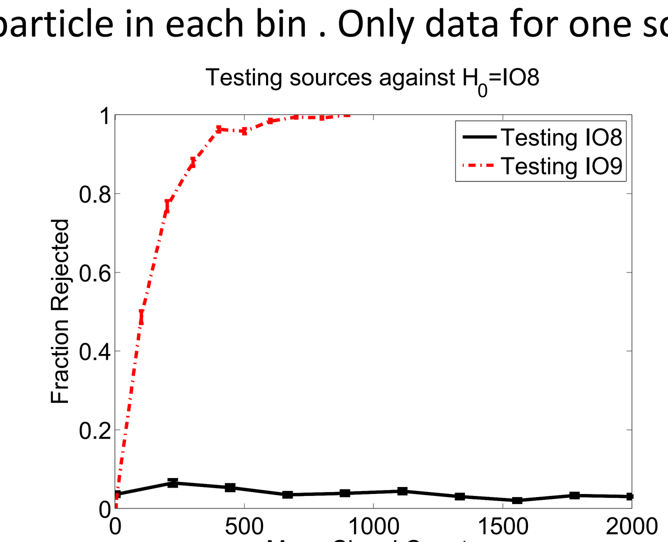
Null Hypothesis test using likelihood model

Theory

We use the likelihood model developed previously to perform a Null Hypothesis test. By using calibration data to create a likelihood model (or template), we can test future sources against this model and possibly reject the null hypothesis.

Information Required

Calibration data is used to find the probability of observing a detected particle in each bin. Only data for one source is required.



(Channelized) Hotelling (Binary Classification)

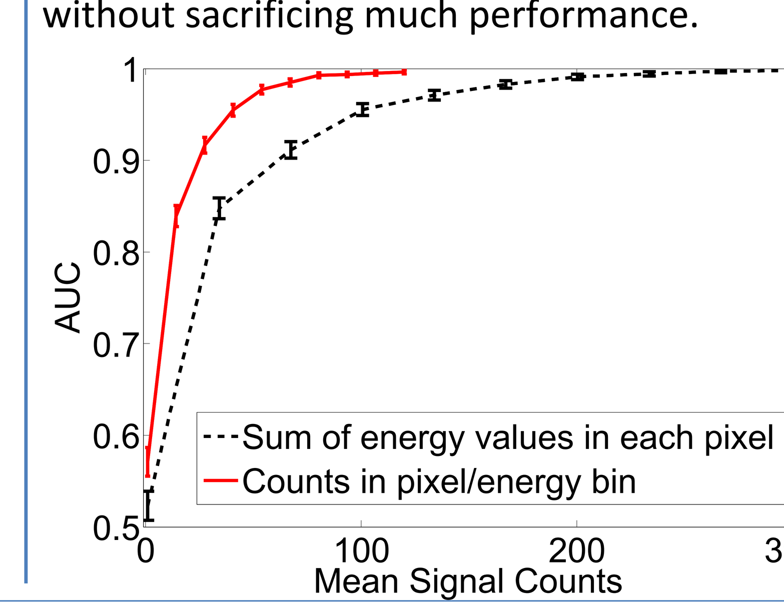
Theory

User defines a template ***T*** that turns list-mode data into vector ***g***. Template is user's choice. Linear discriminant ***w*** acts on this vectorized data to produce test statistic. ***w*** maximizes SNR of test statistic distributions

$$t = \mathbf{w}^t\mathbf{g} = \sum_{n=1}^{N}\sum_{m=1}^{M} w_m T_m(A_n)$$

Information Required

First and second order statistics of vector ***g*** are only variables to be stored. User can choose *T* to ideally store as little data as possible without sacrificing much performance.



Choosing *T* to use counts in each pixel and energy bin: most information, best performance

Choosing *T* to use sum of energies in each bin: less information but worse performance.

Challenges/Plans

Challenges

- How to quantify information sensitivity?
- Prove existence of observer with information sufficient for confirmation but not sensitive.
- Reduce effect of nuisance parameters via marginalization—need CPU time to simulate or tricks such as template morphing.

Plans

- Continue exploring trade space of information required vs performance of observer models.
- Consider techniques for optimizing channelization, including a penalty term for information sensitivity.
- Investigate further nuisance parameters such as background model, source position, and material age.
- Use actual imager data to evaluate task/observer performance.

This work is supported by the Office of Defense Nuclear Nonproliferation Research and Development, Nuclear Weapon and Material Security Team. Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000. (SAND2015-XXXX)