Evaluation of Target Detection Algorithms for Explosive Material Detection using Hyperspectral Imaging and NVIDIA® GPUs

Blas Trigueros Espinosa, Samuel Rosario Torres, Dr. Miguel Vélez Reyes – Advisor, Dr. Nayda Grisel Santiago Santiago – Co-advisor
E-mail: blas.trigueros@upr.edu, samuel.rosario@ece.uprm.edu, miguel.velez7@upr.edu, nayda.santiago@ece.uprm.edu

Laboratory for Applied Remote Sensing and Image Processing
University of Puerto Rico-Mayaguez, PR.

Abstract:

The interest in developing surveillance systems for the remote detection of explosives devices and materials has increased in the last few years. Hyperspectral imagery techniques for target detection can be applied for the detection of traces of explosives. However, this is not a trivial task since in most scenarios it is necessary to deal with small target signatures within heavy clutter, along with the large data volumes of the hyperspectral images. This task becomes even more challenging when the application demands the target detection to be performed in real time. In this work, we are exploiting the architecture of the Graphics Processing Units (GPUs), which are designed to perform massively parallel tasks, for the real time implementation of target detection algorithms. We compare the performance of different target detection algorithms implemented on a NVIDIA® GPU platform using the Jacket toolbox for MATLAB®. We are interested in analyzing which target detection algorithm has a more suitable structure for parallelization in order to speed up the detection process, by taking advantage of the parallel computation capabilities of the GPU. The final objective of this work is to implement a target detection algorithm for the detection of small traces of explosives using a GPU-based platform to speed up the detection process, in order to be able to design a stand-off surveillance system for real time detection.

State of the Art:

Detection of explosive related threats using hyperspectral data could be achieved by:

✓Detection of explosive vapors which escape from a container into the air [1]
✓Detection of traces of explosive material in clothing, containers and automobiles [1,2]
✓Detection of unusual behavior in hyperspectral imagery [3]

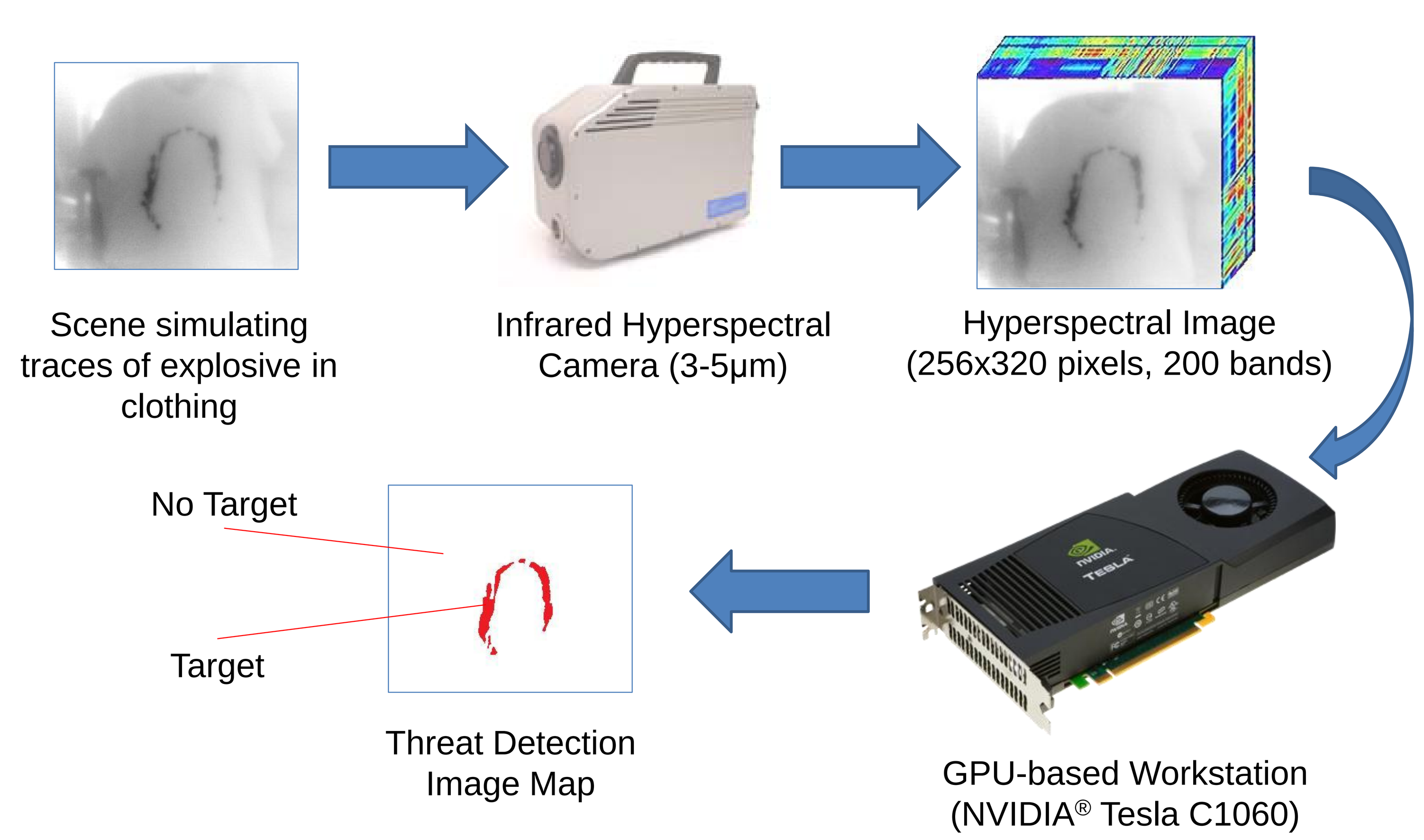
Challenges:

✓Most explosives are formulated to have extremely low vapor pressure
✓The detection of explosive traces presents issues like dealing with small target signatures under heavy clutter and the large data volumes of hyperspectral images.
✓Graphics Processing Units (GPUs) promise to be a suitable platform for solving hyperspectral image processing problems, because they are designed to perform intensive tasks in parallel.

Methodology:

Experimental Setup:

✓A scene was prepared simulating explosive traces on clothing.
✓A hyperspectral image of the scene is registered using a Sherlock® FE infrared camera.
✓The hyperspectral cube is processed using different target detection algorithms running on a NVIDIA® Tesla C1060 GPU.



Technical Approach:

The following target detection algorithms were implemented using the Jacket Engine for MATLAB® [4]. Jacket introduces new data types to MATLAB allowing to move the data and computations to the GPU.

✓**Full-pixel target detectors [5]:**

•Neyman-Pearson Detector:

$$y = D(\mathbf{x}) = (\mathbf{x}-\boldsymbol{\mu}_0)^T \boldsymbol{\Gamma}_0^{-1}(\mathbf{x}-\boldsymbol{\mu}_0) - (\mathbf{x}-\boldsymbol{\mu}_1)^T \boldsymbol{\Gamma}_1^{-1}(\mathbf{x}-\boldsymbol{\mu}_1)$$

•Matched Filter Detector:

$$y = D(\mathbf{x}) = \frac{(\boldsymbol{\mu}_1-\boldsymbol{\mu}_0)^T \boldsymbol{\Gamma}^{-1}(\mathbf{x}-\boldsymbol{\mu}_0)}{(\boldsymbol{\mu}_1-\boldsymbol{\mu}_0)^T \boldsymbol{\Gamma}^{-1}(\boldsymbol{\mu}_1-\boldsymbol{\mu}_0)}$$

$\boldsymbol{\mu}_0$: background mean
$\boldsymbol{\mu}_1$: target mean
$\boldsymbol{\Gamma}_i$: covariance matrix

✓**Subpixel target detectors:**

•Generalized Likelihood Ratio Test (GLRT) Detector:

$$y = D(\mathbf{x}) = \frac{\mathbf{x}^T(\mathbf{P}_B^{\perp} - \mathbf{P}_{SB}^{\perp})\mathbf{x}}{\mathbf{x}^T \mathbf{P}_{SB}^{\perp}\mathbf{x}}$$

•Orthogonal Subspace Projector (OSP):

$$y = D(\mathbf{x}) = \mathbf{s}\mathbf{P}_B^{\perp}\mathbf{x}$$

$\mathbf{P}_B^{\perp}$: orthogonal projection matrix (background)
$\mathbf{P}_{SB}^{\perp}$: orthogonal projection matrix (target + background)
$\mathbf{s}$: target signature

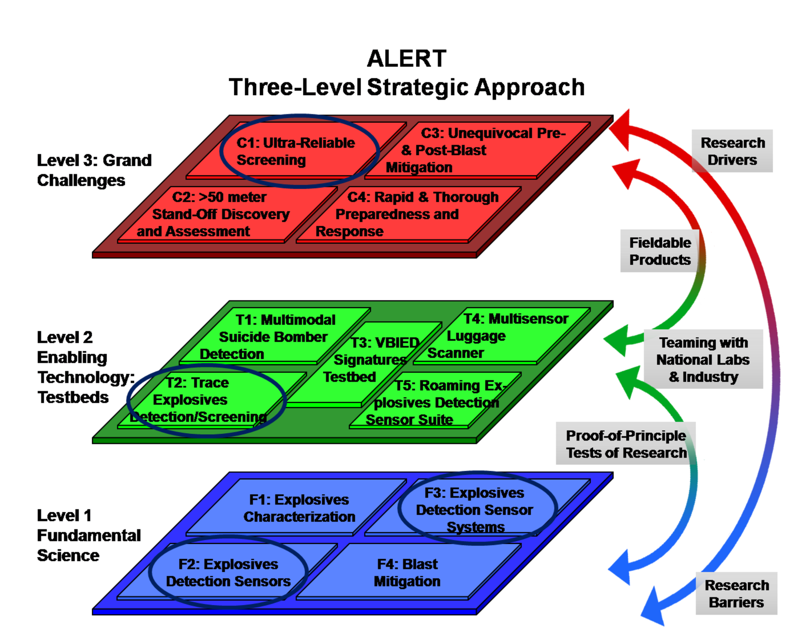
Technology transfer:

The final objective of this work is to implement a target detection algorithm for the detection of small traces of explosives using a GPU-based platform to speed up the detection process, in order to be able to design a stand-off surveillance system for real time detection.

Acknowledgments:

✓This material is based upon work supported by the U.S. Department of Homeland Security under Award Number 2008-ST-061-ED0001. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied of the U.S. Department of Homeland Security.

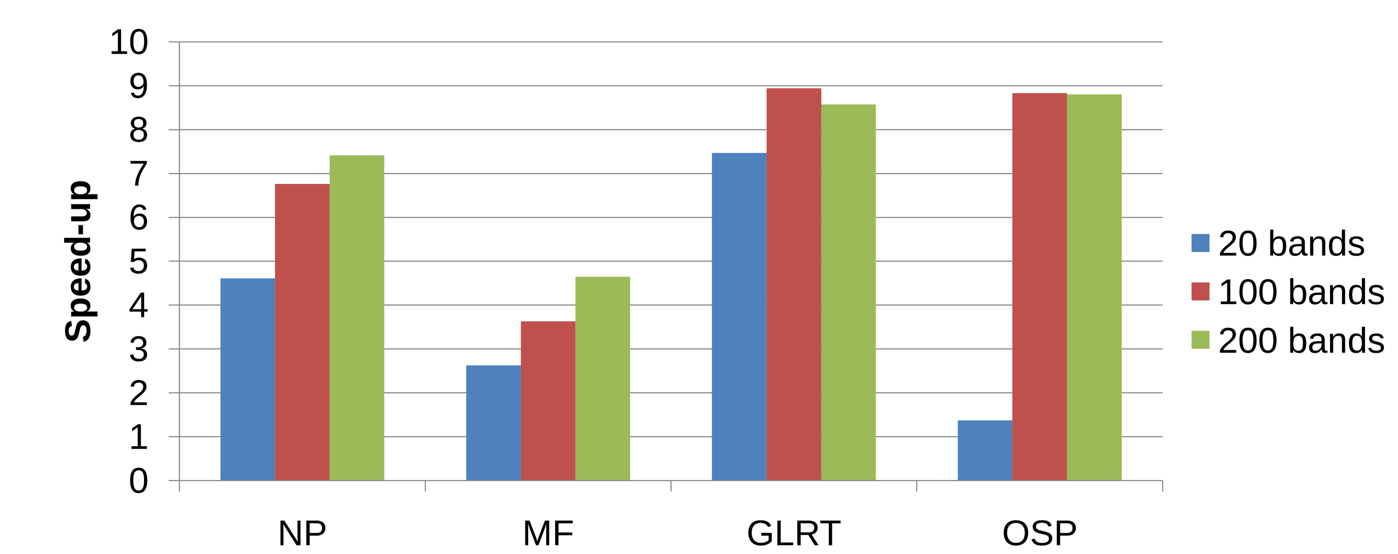
✓Data collection: Dr. Max Diem and Dr. Miloš Miljković, Department of Chemistry & Chemical Biology, Northeastern University (Boston, MA).



Results to date:

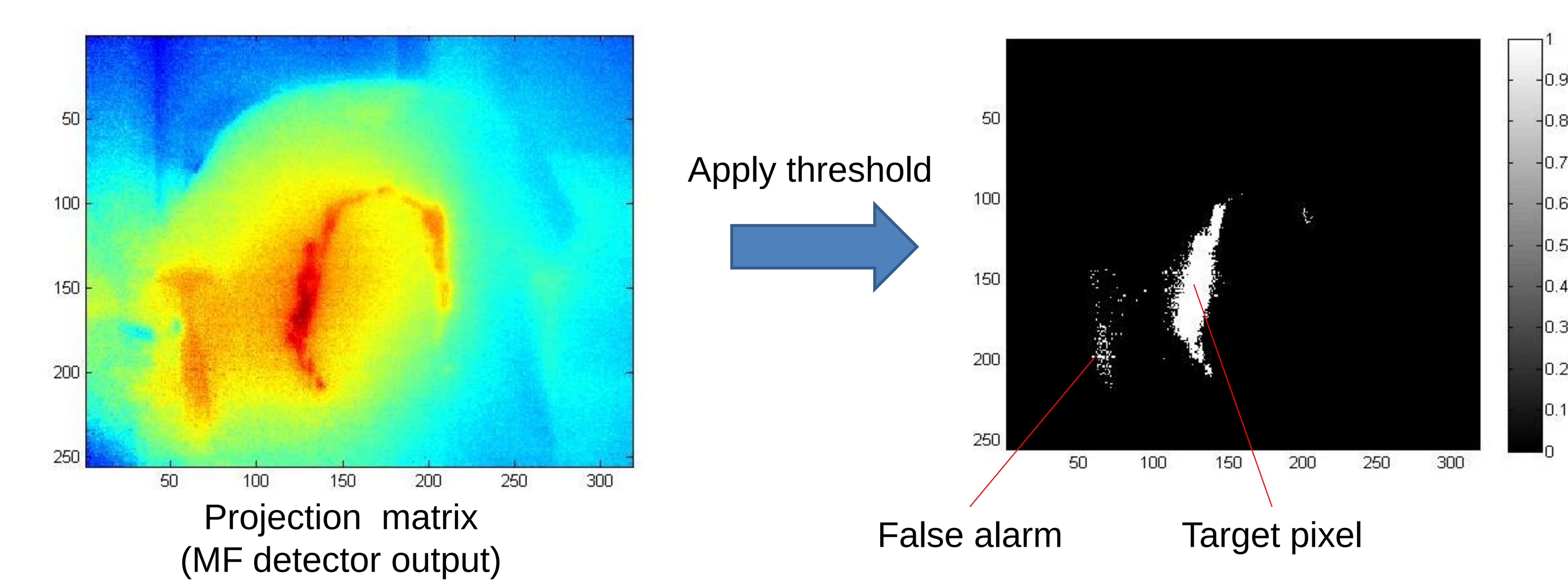
Speedup of the GPU implementation over CPU serial implementation:

The computation time of the GPU implementation was measured for the different detection algorithms and compared to the computation time of the standard MATLAB implementation running on a quad-core Intel Xeon® processor.



We achieved a maximum speedup of about 9x for the GLRT and OSP detectors. In general, the speedup increases with the number of bands.

Detection results:



References:

[1] H.C. Schau and B.D. Jennette, "Hyperspectral requirements for detection of trace explosive agents". In Proceedings of SPIE: Algorithms and Technologies for Multispectral, Hyperspectral, and Ultraspectral Imagery XII, Vol. 6233, 2006.
[2] M. Dombrowski, P. Wilson, and C. LaBow, "Defeating camouflage and finding explosives through spectral matched filter of hyperspectral imagery". Proceeding of SPIE, Vol. 2933, 1997.
[3] P. Chishol, "Clearing the roads", Specials Operations Technology, Volume 5, Issue 4, June 4, 2007. http://www.specialoperations- technology.com/
[4] http://www.accelereyes.com/
[5] D. Manolakis, D. Marden, G.A. Shaw, "Hyperspectral image processing for automatic target detection applications." In Lincoln Laboratory Journal, Vol. 14, No. 1, 2003.