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Dominic Ho

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14. ABSTRACT
We have developed innovative signal processing techniques to advance the performance of the vehicle mounted and handheld based ground penetrating radars for the detection of subsurface objects that are low in metal content and hard to detect. The derived techniques include the exploitation of frequency responses of the subsurface objects, the application of auto-regressive modelling and the use of matrix decomposition method. The developed techniques have been transferred to the DoD and the DoD's contractors that build the ground penetrating radar detection systems

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a. REPORT	b. ABSTRACT	c. THIS PAGE			Dominic Ho
UU	UU	UU	UU		19b. TELEPHONE NUMBER: 573-882-8023

Report Title

Advanced Statistical Signal Processing Techniques for Landmine Detection Using GPR

ABSTRACT

We have developed innovative signal processing techniques to advance the performance of the vehicle mounted and handheld based ground penetrating radars for the detection of subsurface objects that are low in metal content and hard to detect. The derived techniques include the exploitation of frequency responses of the subsurface objects, the application of auto-regressive modelling and the use of matrix decomposition method. The developed techniques have been transferred to the DoD and the DoD's contractors that build the ground penetrating radar detection systems.

Enter List of papers submitted or published that acknowledge ARO support from the start of the project to the date of this printing. List the papers, including journal references, in the following categories:

(a) Papers published in peer-reviewed journals (N/A for none)

Received		Paper
03/04/2011	2.00	T. Glenn, J. Wilson, D. Ho. A MULTIMODAL MATCHING PURSUITS DISSIMILARITY MEASURE APPLIED TO LANDMINE/CLUTTER DISCRIMINATION, IEEE, (01 2010): . doi:
03/04/2011	8.00	W. Ng, T. Chan, H. So, D. Ho. ON PARTICLE FILTERS FOR LANDMINE DETECTION USING IMPULSE GROUND PENETRATING RADAR, , (01 2008): . doi:
03/04/2011	7.00	W. Ng, T. Chan, H. So, D. Ho. Particle Filtering Based Approach for Landmine Detection Using Ground Penetrating Radar, IEEE Transactions on Geoscience and Remote Sensing, (11 2008): . doi:
03/04/2011	6.00	D. Ho, P. Gader, J. Wilson, H. Frigui. On Improving Subspace Spectral Feature Technique for the Detection of Weak Scattering Plastic Antitank Landmines , Proceedings of SPIE, (01 2009): . doi:
03/04/2011	5.00	T. Havens, C. Spain, D. Ho, J. Keller, T. Ton, D. Wong, M. Soumekh. Improved Detection and False Alarm Rejection Using FLGPR and Color Imagery in a Forward-Looking System, Proceedings of SPIE, (01 2010): . doi:
03/04/2011	4.00	T. Havens, D. Ho, J. Farrell, J. Keller, M. Popescu, T. Ton, D. Wong. Locally-Adaptive Detection Algorithm for Forward-Looking Ground Penetrating Radar, Proceedings of SPIE, (01 2010): . doi:
03/04/2011	3.00	D. Ho, P. Gader, J. Wilson, H. Frigui. Effect of Radar Undesirable Characteristics on the Performance of Spectral Feature Landmine Detection Technique, Proceedings of SPIE, (01 2010): . doi:
03/07/2011	9.00	D. Ho, J. Wilson, P. Gader. On the Use of Aggregation Operator For Humanitarian Demining Using Hand-Held GPR, , (01 2008): . doi:
03/07/2011	12.00	D. Ho, P. Gader, J. Wilson, H. Frigui. Subspace Processing of GPR Signals for Vehicle-Mounted Landmine Detection System, Proceedings of SPIE, (01 2008): . doi:
03/07/2011	10.00	T. Chan, H. So, D. Ho. Generalized two-sided linear prediction approach for land mine detection, Signal Processing, (01 2008): . doi:
03/07/2011	11.00	D. Ho, L. Carin, P. Gader, J. Wilson. An Investigation of Using the Spectral Characteristics From Ground Penetrating Radar for Landmine/Clutter Discrimination, IEEE Transactions on Geoscience and Remote Sensing, (04 2008): . doi:
07/12/2014	27.00	Seniha Esen Yuksel, Ganesan Ramachandran, Paul Gader, Joseph Wilson, Dominic Ho, Gyeongyong Heo. Hierarchical methods for landmine detection with wideband electro-magnetic induction and ground penetrating radar multi-sensor systems, IEEE International Geoscience and Remote Sensing Symposium, (07 2008): 177. doi:

07/26/2012	22.00	Lijun Zhang, Paul Gader, Joseph N. Wilson, Dominic K.C. Ho, Andres Mendez-Vazquez, Hichem Frigui. An evaluation of several fusion algorithms for anti-tank landmine detectionand discrimination, Information Fusion, (04 2012): 161. doi:

TOTAL: **13**

Number of Papers published in peer-reviewed journals:

(b) Papers published in non-peer-reviewed journals (N/A for none)

Received	Paper

TOTAL:

Number of Papers published in non peer-reviewed journals:

(c) Presentations

Number of Presentations: 0.00

Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received		Paper
07/09/2013	25.00	Alina Zare, Dominic K. C. Ho, Josephine Dula, Paul Gader. Landmine Classification Using Possibilistic K-Nearest Neighbors withWideband Electromagnetic Induction Data, SPIE Conf. Detection and Sensing of Mines, Explosive Objects, and Obscured Targets XVIII. 29-JUL-13, . : ,
07/09/2013	26.00	Dominic K. C. Ho, Daniel P. Nabelek. Detection of shallow buried objects using an autoregressive model on the ground penetrating radar signal, SPIE Conf. Detection and Sensing of Mines, Explosive Objects, and Obscured Targets XVIII. 29-JUL-13, . : ,
07/25/2012	21.00	Justin Farrell, Timothy C. Havens, Dominic K. C. Ho, James M. Keller, Tuan T. Ton, David C. Wong, Mehrdad Soumekh. Evaluation and Improvement of Spectral Features for the Detection of Buried Explosive Hazards Using Forward-Looking Ground-Penetrating Radar, Conf. Detection and Sensing of Mines, Explosive Objects, and Obscured Targets XVII. 23-JUL-12, . : ,
07/25/2012	20.00	Dominic K.C. Ho, Paul D. Gader. On The Estimation of Target Depth Using the Single Transmit Multiple Receive Metal Detector Array, SPIE Conf. Detection and Sensing of Mines, Explosive Objects, and Obscured Targets XVII. 23-APR-12, . : ,
08/08/2012	23.00	Timothy C. Havens, Kevin Stone, Derek T. Anderson, James M. Keller, Dominic K.C. Ho, Tuan T. Ton, David C. Wong , Mehrdad Soumekh. multiple Kernel Learning For Explosive Hazard Detection in Forward-Looking Ground-Penetrating Radart, SPIE Conf. Detection and Sensing of Mines, Explosive Objects, and Obscured Targets XVII. 23-APR-12, . : ,
12/03/2011	19.00	Dominic Ho, Paul Gader, Joseph Wilson, Hichem Frigui. On Improving the Efficiency of Subspace SCF Landmine Detection Method, ARO Landmine & Buried Explosive Object Detection Research Review Meeting. 02-FEB-11, . : ,
12/03/2011	17.00	Timothy C. Havens, K.C. Ho, James M. Keller , Tuan T. Ton, David C. Wong, Mehrdad Soumekhc, Justin Farrell . Detection of Explosive Hazards Using Spectrum Features From Forward-Looking Ground Penetrating Radar Imagery, SPIE Conf. Detection and Sensing of Mines, Explosive Objects, and Obscured Targets XVI. 23-MAY-11, . : ,
12/03/2011	18.00	Timothy C. Havens, James M. Keller, K. C. Ho, Tuan T. Ton, David C. Wong, Mehrdad Soumekh. Narrow-Band Processing and Fusion Approach for Explosive Hazard Detection in FLGPR, SPIE Conf. Detection and Sensing of Mines, Explosive Objects, and Obscured Targets XVI. 25-MAY-11, . : ,

TOTAL: **8**

Number of Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received	Paper

TOTAL:

Number of Peer-Reviewed Conference Proceeding publications (other than abstracts):

(d) Manuscripts

Received		Paper
03/04/2011	1.00	H. Frigui, L. Zhang, P. Gader, J. Wilson, D. Ho, A. Mendez-Vazquez. An evaluation of several fusion algorithms for anti-tank landmine detection and discrimination, (01 2009)
12/03/2011	15.00	Hichem Frigui, Lijun Zhang, Paul Gader, Joseph N Wilson, K C Ho, Andres Mendez-Vazquez. An evaluation of several fusion algorithms for anti-tank landmine detection and discrimination, Elsevier Preprint (01 2009)

TOTAL: **2**

Number of Manuscripts:

Books

Received	Book

TOTAL:

Received Book Chapter

TOTAL:

Patents Submitted

Patents Awarded

Awards

Dominic Ho received the Senior Faculty Research Award from the College of Engineering at the University of Missouri in March 2009.

Dominic Ho was elected to be a Fellow of the IEEE in January 2009.

Dominic Ho received the Distinguished Alumni Award from the Chinese University of Hong Kong in April 2012.

Dominic Ho received the Senior Faculty Research Award from the College of Engineering at the University of Missouri in March 2014.

Dominic Ho has been elected to be the Chair of the Sensor Array and Multichannel Technical Committee of the IEEE Signal Processing Society.

Dominic Ho has been invited to be in the Technical Program Committee of the 8th IEEE International Workshop on Sensor Array and Multichannel signal Processing, A Coruna, June 2014.

Dominic Ho has been listed in Who's Who in Education, Marquis.

Dominic Ho has been listed in Who's Who in Science and Engineering, Marquis.

Dominic Ho has been listed in Who's Who in America, Marquis.

Dominic Ho has been listed in Who's Who in the World, Marquis.

Graduate Students

NAME	PERCENT_SUPPORTED	Discipline
Daniel Nabelek	0.50	
Liyang Rui	0.50	
Le Yang	0.50	
Shanjie Chen	0.50	
Zhenhua Ma	0.50	
Josephine Dula	0.50	
FTE Equivalent:	**3.00**	
Total Number:	**6**	

Names of Post Doctorates

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Names of Faculty Supported

NAME	PERCENT_SUPPORTED	National Academy Member
Dominic Ho	0.15	
Alina Zare	0.10	
FTE Equivalent:	**0.25**	
Total Number:	**2**	

Names of Under Graduate students supported

NAME	PERCENT_SUPPORTED	Discipline
Daniel Nabelek	0.50	BS
FTE Equivalent:	**0.50**	
Total Number:	**1**	

Student Metrics

This section only applies to graduating undergraduates supported by this agreement in this reporting period

The number of undergraduates funded by this agreement who graduated during this period: 1.00

The number of undergraduates funded by this agreement who graduated during this period with a degree in science, mathematics, engineering, or technology fields:..... 1.00

The number of undergraduates funded by your agreement who graduated during this period and will continue to pursue a graduate or Ph.D. degree in science, mathematics, engineering, or technology fields:..... 1.00

Number of graduating undergraduates who achieved a 3.5 GPA to 4.0 (4.0 max scale):..... 1.00

Number of graduating undergraduates funded by a DoD funded Center of Excellence grant for Education, Research and Engineering:..... 0.00

The number of undergraduates funded by your agreement who graduated during this period and intend to work for the Department of Defense 0.00

The number of undergraduates funded by your agreement who graduated during this period and will receive scholarships or fellowships for further studies in science, mathematics, engineering or technology fields: 0.00

Names of Personnel receiving masters degrees

NAME	
Josephine Dula	
Total Number:	**1**

Names of personnel receiving PHDs

NAME	
Le Yang	
Zhenhua Ma	
Total Number:	**2**

Names of other research staff

NAME	PERCENT_SUPPORTED
Lori Thunhorst	0.05
FTE Equivalent:	**0.05**
Total Number:	**1**

Sub Contractors (DD882)

Inventions (DD882)

Scientific Progress

We have developed innovative signal processing techniques for the vehicle-mounted and handheld ground penetrating radars for subsurface object detection. The techniques are particularly useful to detect the difficult targets that could be deeply buried and low in metal content. The techniques have gone through blind tests from the government and some of them has been implemented for use in the actual systems.

Technology Transfer

Research and Accomplishments

We have developed innovative signal processing techniques for the vehicle-mounted and handheld ground penetrating radars for subsurface object detection. The techniques are particularly useful to detect the difficult targets that could be deeply buried and/or low in metal content. We have summarized and documented our research investigations in the published papers.

For the vehicle-mounted ground penetrating radar, two techniques have been developed. The first technique is based on the frequency spectra of the targets to distinguish between targets and clutter objects. The second uses the auto-regressive modelling technique to improve the detection of shallow low-metal content targets. All of these techniques have been transferred to the government and the government's contractors. These techniques have gone through blind tests from the government. They have been implemented for use in the actual system.

For the handheld ground penetrating radar, we have advanced the linear predictor pre-processing and developed adaptive algorithms to enhance the performance. The developed techniques have been implemented in the actual handheld system AN/PSS-14, and they have assisted L3 Communications - CyTerra Corporation in passing the requirements for the blind test evaluations.

Technology Transfer

We have transferred the developed ground penetrating radar processing techniques, both vehicle-mounted and handheld-based, to the government, and the government's contractors Niitek Inc. and L3 Communications - CyTerra Corp. The techniques have already been implemented by the contractors for use in their hardware platforms.