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Assessing the Capability of Advanced Geophysical Classification Techniques to Inform Minimum Separation Distances for UXO Remediation (Poster)

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About This Publication

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Executive Summary

Introduction

From 2007 to 2017, the Environmental Security Technology Certification Program (ESTCP) sponsored a series of live-site demonstrations to assess the capabilities of newly developed advanced geophysical classification (AGC) technologies to detect and classify buried targets of interest (TOI) (unexploded ordnance (UXO), inert and surrogate munitions, seeds, and any other objects for which the site team agrees that removal is required). These technologies have been shown to detect TOI and reject clutter with a high probability of detection and low probability of false alarm, saving the DoD in remediation costs. Previous retrospective analyses summarized the capabilities of AGC to differentiate TOI from clutter without taking the size of the detected objects into account. The capability to predict the size of a buried object could allow the DoD to more appropriately set the minimum safe distance (MSD) in UXO remediation projects, thus saving more in remediation costs. We have therefore conducted a retrospective analysis of the ESTCP live-site demonstrations in order to determine the capabilities of AGC to inform the MSD.

Results

For 104 Ranked Anomaly Lists (RALs) from 10 live-site demonstrations, IDA retrieved the actual and predicted sizes for every TOI. The sizes were binned into small (< 50 mm diameter), medium (>= 50 mm and < 100 mm), or large (>= 100 mm) categories. A confusion matrix was created for each RAL, and the numbers of TOI in each category were assessed. In particular, attention was paid to the number of TOI that were predicted to be in a smaller category than their actual size, as this type of error would lead to a dangerously short MSD. We found that size predictions were correct for the majority (90%) of TOI, and when predictions were incorrect, they tended to err on the side of caution (predicted larger than reality 7% of the time). Only 3% of predictions were unsafe (predicted smaller than reality), and in only one instance out of 104 RALs was a large TOI predicted to be in a small size category.

Conclusions

AGC technologies show evidence of being able to predict the size category of buried TOI. This capability could be used to help set the MSD in UXO remediation projects.

Assessing the Capability of Advanced Geophysical Classification Techniques to Inform Minimum Separation Distances in UXO Remediation

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Introduction

- Through FY2018, 2,301 formerly used defense sites are known to contain **unexploded ordnance (UXO)**, discarded military munitions, or munition contaminants OSD(A&S) (2019) Defense Environmental Programs Annual Report to Congress for Fiscal Year 2018

UXO

- From 2007 – 2017, the Environmental Security Technology Certification Program (ESTCP) sponsored a series of live-site demonstrations to assess the capability of **advanced geophysical classification (AGC)** for safely remediating land of UXO while reducing remediation costs
- Demonstration results showed that AGC could **detect and correctly classify Targets of Interest (TOI)** with a high P_d and reject clutter with a low P_{fa}

> TOI = UXO, inert and surrogate munitions, seeds, and any other objects for which the site team agrees that removal is required

- IDA has now retrospectively analyzed the demonstration results to assess how well AGC can **predict the TOI size**
- Correct prediction of TOI size could inform **Minimum Separation Distances (MSD)** set during UXO remediation, further reducing remediation costs

Methods

- Demonstrators collected and processed data to produce a **ranked anomaly list**
- In previous analyses, the Category and Dig Decision columns were scored against ground truth to produce a Receiver-Operating Characteristic (ROC) Curve describing the capability of AGC to classify TOI vs. clutter Cazares, Ayers, and Tuley (2017) UXO Live Site Classification Demonstrations: A Retrospective Summary. SERDP & ESTCP Symposium 2017. Washington, DC, 28-30 November 2017
- In this analysis, the TOI Size column was scored against ground truth to produce a **Confusion Matrix** describing the capability of AGC to predict the TOI size for all "TOI events", i.e., true TOI that were detected and correctly classified
- Each TOI at each demonstration was assigned a size label of Small, Medium, or Large based on its caliber or diameter

Size	Caliber or Diameter (mm)
Small	<50
Medium	>=50 and <100
Large	>=100

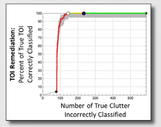
- IDA summarized the confusion matrices from all 104 final ranked anomaly lists submitted from all 10 demonstrations that were representative of real-world UXO remediation projects and for which TOI size was predicted:
  - Tallies were made for the number of TOI size predictions that **matched ground truth**, were **larger than ground truth**, and were **smaller than ground truth**
  - Those TOI size predictions that were smaller than ground truth were assessed in more detail, since these **too-small predictions would have informed a too-short MSD** in a UXO remediation project

Ranked Anomaly List

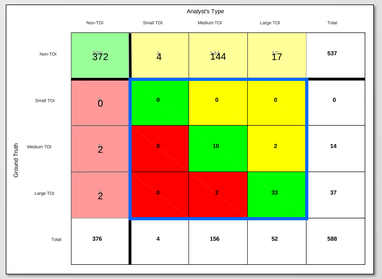
Target ID	Category	Dig Decision	TOI Size
XX-2003	Cannot Analyze	Excavate	N/A
XX-2013	Cannot Analyze	Excavate	N/A
XX-2030	Cannot Analyze	Excavate	N/A
...	...	...	...
XX-2323	Training Set	Excavate	N/A
XX-2338	Training Set	Excavate	N/A
...	...	...	...
XX-2413	Likely TOI	Excavate	Large
XX-2504	Likely TOI	Excavate	Medium
XX-2665	Likely TOI	Excavate	Medium
XX-2503	Likely TOI	Excavate	Small
XX-2278	Likely TOI	Excavate	Large
...	...	...	...
XX-2677	Cannot Decide	Excavate	Medium
XX-2364	Cannot Decide	Excavate	Small
XX-2616	Cannot Decide	Excavate	Small
...	...	...	...
XX-2674	Likely Clutter	Leave Unexcavated	N/A
XX-2058	Likely Clutter	Leave Unexcavated	N/A
XX-2274	Likely Clutter	Leave Unexcavated	N/A
XX-2054	Likely Clutter	Leave Unexcavated	N/A
XX-2541	Likely Clutter	Leave Unexcavated	N/A
...	...	...	...

TOI Likelihood Rank

ROC Curve



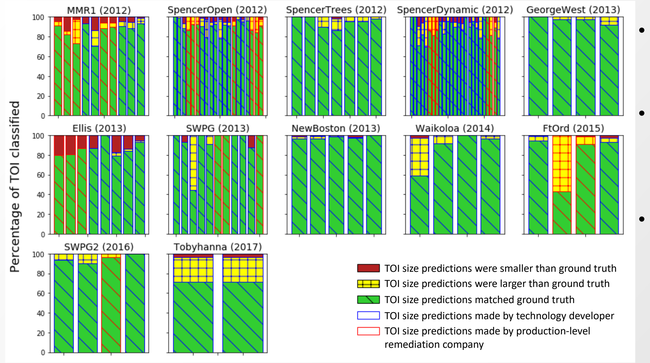
Confusion Matrix



TOI events = true TOIs detected and correctly classified

Results

TOI Size Prediction Performance of 104 Ranked Anomaly Lists submitted from 10 demonstrations:



- Each plot corresponds to one subsite of a demonstration
- Each bar corresponds to one Ranked Anomaly List submitted from that subsite
- Colors/shadings refer to the percentage of TOIs on that Ranked Anomaly List with correct, too-small, and too-large size predictions.

Overall unweighted averages:

- 89.85% (5,065/5,637) of TOI size predictions matched ground truth
- 7.38% (416/5,637) of TOI size predictions were larger than ground truth
- 2.77% (156/5,637) of TOI size predictions were smaller than ground truth

TOI sizes predicted smaller than ground truth:

Ground truth	Prediction	Number
Large	Small	1
Large	Medium	67
Medium	Small	88

- 0.02% (1/5,637) TOI events involved truly large TOIs predicted to be small: a 155-mm projectile at 52-cm depth, analyzed by a **production-level remediation company that was new to AGC**. All other demonstrators accurately predicted the size of this TOI
- 1.56% (88/5,637) TOI events involved truly medium TOIs predicted to be small. 36 of these 88 (41%) were **grenades**, all at Ellis.
  - Grenades were assigned a ground truth label of "medium" due to their diameter.
  - In retrospect, grenades could have been assigned a ground truth label of "small" due to their overall size

Discussion

- **AGC has demonstrated the capability to predict the size category (small vs. medium vs. large) of a buried TOI in most cases. TOI size prediction could inform the MSD in UXO remediation:**
  - ≈90% (5,065/5,637) of TOI size predictions matched ground truth and would have informed an appropriate MSD
  - ≈7% (416/5,637) of TOI size predictions were larger than ground truth and would have informed a too-long MSD (erring on the side of caution)
  - ≈3% (156/5,637) of TOI size predictions were smaller than ground truth and would have informed a too-short MSD
    - Only 1 large TOI was predicted to be small: a 155-mm projectile at 52-cm depth, analyzed by a production-level remediation company that was new to AGC. More training may have improved their performance
    - 88 TOI events involved truly medium TOIs predicted to be small. 36 of these were grenades. Assigning ground truth labels based on overall size, rather than diameter, would have improved scores
- **It is possible that TOI size prediction performance may improve further due to quality control and accreditation processes implemented after these demonstrations took place (DAGCAP, QAPP, RCA/CA, etc)**

Sponsored by the Environmental Security Technology Certification Program (ESTCP)

The following information may be discussed in relation to the poster on page 1

Inert UXO seeded at the ESTCP live site demonstration at Camp Ellis, IL.

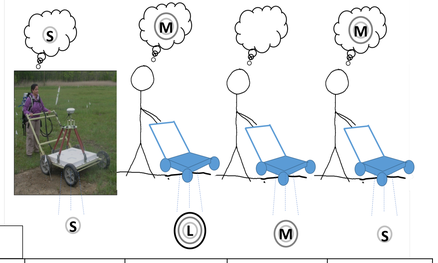
The cutoff for the “small” size category varied by up to 4mm in two early sites: Spencer and Ellis

Site	Year	Small size (mm)
MMR1	2012	< 50
Spencer	2012	< 54
GeorgeWest	2013	< 50
Ellis	2013	< 53
SWPG	2013	< 50
NewBoston	2013	< 50
Waikoloa	2014	< 50
FtOrd	2015	< 50
SWPG2	2016	< 50
Tobyhanna	2017	< 50

Future work

- More formally address the statistical dependence between multiple TOI events based on the same individual TOI. All RALs from the same demonstration contain (at least some of) the same TOI as each other.
- Conduct a detailed analysis of the sizes of false positives and false negatives (if any) in TOI vs. clutter classification
- Consider more specific size predictions, e.g. “105 mm” instead of “large”

The difference between data used for ROC curves and data used in this analysis



Analysis				
TOI vs. clutter classification	*TOI Detected & Correctly Classified*	*TOI Detected & Correctly Classified*	*TOI NOT Detected or NOT Correctly Classified*	*TOI Detected & Correctly Classified*
TOI size prediction	correct	too small	---	too large
informing MSD	appropriate	too short	---	too long

ROC curves (not shown here)

Confusion matrices

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14. ABSTRACT

Introduction: From 2007 to 2017, the Environmental Security Technology Certification Program (ESTCP) sponsored a series of live-site demonstrations to assess the capabilities of newly developed advanced geophysical classification (AGC) technologies to detect and classify buried targets of interest (TOI) (unexploded ordnance (UXO), inert and surrogate munitions, seeds, and any other objects for which the site team agrees that removal is required). These technologies have been shown to detect TOI and reject clutter with a high probability of detection and low probability of false alarm, saving the DoD in remediation costs. Previous retrospective analyses summarized the capabilities of AGC to differentiate TOI from clutter without taking the size of the detected objects into account. The capability to predict the size of a buried object could allow the DoD to more appropriately set the minimum separation distance (MSD) in UXO remediation projects, thus saving more in remediation costs. We have therefore conducted a retrospective analysis of the ESTCP live-site demonstrations in order to determine the capabilities of AGC to inform the MSD. Results: For 104 Ranked Anomaly Lists (RALs) from 10 live-site demonstrations, IDA retrieved the actual and predicted sizes for every TOI. The sizes were binned into small (< 50 mm diameter), medium (>= 50 mm and < 100 mm), or large (>= 100 mm) categories. A confusion matrix was created for each RAL, and the numbers of TOI in each category were assessed. In particular, attention was paid to the number of TOI that were predicted to be in a smaller category than their actual size, as this type of error would lead to a dangerously short MSD. We found that size predictions were correct for the majority (90%) of TOI, and when predictions were incorrect, they tended to err on the side of caution (predicted larger than reality 7% of the time). Only 3% of predictions were unsafe (predicted smaller than reality), and in only one instance out of 104 RALs was a large TOI predicted to be in a small size category. Conclusions: AGC technologies show evidence of being able to predict the size category of buried TOI. This capability could be used to help set the MSD in UXO remediation projects.

15. SUBJECT TERMS

advanced geophysical classification (AGC); Environmental Security Technology Certification Program (ESTCP); minimum separation distance (MSD); Ranked Anomaly Lists (RALs); targets of interest (TOI); unexploded ordnance (UXO)

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