

Detection of chemical explosives in targets that contain other materials

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Introduction

Improvised explosive devices (IEDs) are a common weapon in the arsenal of terrorists. Methods to detect IEDs rapidly and from standoff are needed. The fact that materials other than chemical explosives may be present in IEDs, in arbitrary amounts and configurations, complicates detection.



Nomenclature

We use the nomenclature that

- A **target** is an object with at least one exposed surface
- An **explosive** is a nitrogen-rich chemical explosive
- A material is **inert** if it is not an explosive
- A **sample** is an object, which can be either explosive or inert, within a target
- **Clutter** is the collection of items other than the sample that are present within a target.

We seek a standoff method to differentiate targets that contain explosive samples from those that do not, in the presence of clutter.

Signature-based radiation scanning

The signature-based radiation scanning (SBRS) technique seeks to detect IEDs, even in the presence of clutter, using active radiation scanning in back-streaming mode. We irradiate targets with photon and neutron beams and collect back-streaming radiation responses, which we call signatures. Many photon, neutron, and neutron-generated (prompt-capture and inelastic-scatter) gamma-ray signatures are possible. We interrogate volumes of the order of 7 L (2 gal) and thus large targets must be scanned. We compare the collection of signatures from an unknown target to templates in a library. Each template is the collection of signatures expected if an explosive sample were in the target with some configuration of clutter. We reduce the number of clutter configurations by developing "artificial templates," which are templates characteristic of average clutter compositions and densities.

IEDs are differentiated by use of two filter functions, f and f_+ , whose values are compared to a cut-off value f_0 . A value of f lower than f_0 identifies an IED and a value of f_+ above f_0 identifies an inert target. A tiered approach using artificial templates was investigated. A simulation study, using MCNP5, was conducted to see if a small number of artificial templates can represent a large number of clutter configurations within targets that might be IEDs.

Simulation study

The simulation geometry is shown at right. The beam consisted of 14.1-MeV neutrons, the clutter was one of 25 inert materials, and the sample was either RDX or one of the 25 inert clutter materials. Fifty combinations were simulated

- 25 inert/RDX
- 25 inert/inert

Using only four artificial templates to characterize the following density categories

- Very-low (0 - 0.5 g cm⁻³)
- Low (0.5 - 1.5 g cm⁻³)
- Medium (1.5 - 3 g cm⁻³)
- High (>3 g cm⁻³)

we obtained the results discussed below.

Results

Tier 1. Filtering on the basis of five nitrogen signatures eliminated as inert all but two of the 25 inert/inert targets (N-Fertilizer/N-Fertilizer and Nylon/Nylon) but retained all 25 inert/RDX targets as possible IEDs.

Tier 2. Applying the very-low density artificial template for eight HCNO signatures, two of the 25 inert/RDX targets were clearly differentiated from both remaining inert-inert targets.

Tier 3. Applying the high density artificial template for eight HCNO signatures, two more of the 25 inert-RDX targets were clearly differentiated from both inert/inert targets.

Tier 4. Applying the medium-density artificial template for eight HCNO signatures, 8 more of the 25 inert/RDX targets were clearly differentiated from both inert/inert targets.

Tier 5. Twice applying the low-density artificial template, once normally and once by weighting the signatures, all 13 remaining inert/RDX targets were differentiated from the Nylon/Nylon but not from the N-Fertilizer/N-Fertilizer target.

Thus, using only four artificial templates, we were able to analyze 50 targets with no false negatives and only a single false positive.

Conclusions

It appears to be possible to represent a large number of clutter conditions with only a relatively few artificial templates. Thus, the SBRS technology may be useful in detecting IEDs in a variety of types of targets.

