Simulation of Disturbed Earth and Buried Threat Signature Responses & Optimal Detection Strategies

Fink, Christopher – JRM Technologies

ABSTRACT

Combatant troop movements and buried threats (such as land mines) can often be identified in infrared and radar sensor bands by the physical clues they leave behind.

Buried IEDs introduce regions of significantly altered thermophysical and electromagnetic properties. Density and thermal conductivity changes alter the flow of heat inside the soil layers, resulting in different surface temperatures for the same irradiance load. Meanwhile, electromagnetic property changes affect the amount of backscattered power seen by a radar sensor.

Troop movements compress the soil, making it more dense and less emissive. Conversely, digging operations expand and fragment the soil, making it less dense and more emissive. Such emissivity changes then result in different emitted thermal radiances from these surfaces for the same temperature.

These physical changes can produce signature effects which are highly spectral in nature; for example the long-wave infrared band has been used to detect disturbed earth by looking for the Reststrahlen effect, where abrupt gradients in soil composition lead to increased scattering (reduced emittance) in certain narrow wavebands.

With recent advancements in physics-based sensor-band modeling and simulation, the problem of predicting the signature effects of disturbed soil and buried object regions, and correlating these data with physical changes in the soil, can be approached and more rigorously solved, as a function of environment and sensor properties. Simulating these threats ahead of time can identify those sensor assets and settings, atmospheric conditions, and times-of-day most suitable for locating and identifying the presence of disturbed earth and buried threats.

In this paper, the authors outline the components and requirements for such a simulation and detection prediction system, including:

1. Libraries of measured material property data.
2. Tools for creating 3D terrain databases of the region of interest.
3. Tools for materially-classifying these databases, to associate each location with a set of pertinent material properties.
4. Tools for selecting regions of the terrain at which the soil has been disturbed or threats have been buried, and definition of the material and spatial configuration of the disturbance.
5. Signature Physics libraries which predict spectral scene irradiances, radiative transport coefficients, and resulting surface temperatures, for given atmospheric conditions and date/time-of-day.
6. Sensor Physics libraries which define a sensor's spatial/spectral resolution limitations and predict resulting post-aperture processing effects, such as optical diffraction and motion blur, detector noise, and intensifier haloing, for given user settings.
7. Graphics Tools for rendering and channel-integrating the perceived radiance signature at each terrain point in the FOV (accounting for reflection, emission, and atmospheric degradation), and applying sensor effects.
8. Detection Prediction Models, for quantitatively assessing the image contrast and consequent detectability of the disturbed region relative to its background.

Coupled with advances in computing technology (especially the advent of high-performance commercial graphics processing units), such a system would provide for real-time, in-thefield simulation and decision-making capability for threat avoidance and tracking applications.