Support Vector Machine Classification of Unexploded Ordnance Based on EMI Spheroidal Scattering Mode Coefficients

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This project developed discrimination techniques that might be applied to distinguish unexploded ordnance (UXO) from large clutter pieces using their frequency domain UWB electromagnetic induction (EMI) response measurements. We use a forward scattering model for spheroids to represent UXO because they are typically elongated bodies of revolution. Our forward model describes the EMI response of objects in terms of spheroidal excitation and scattering modes. The coefficients of the scattering modes have been shown to be unique for a given scattering response. Therefore, we use the coefficients of the spheroidal scattering modes as inputs into a support vector machine (SVM), a binary classification algorithm based on statistical learning. We train the SVM by presenting it with the scattering coefficients of objects in known classes. Then, new objects with unknown class can be correctly classified by a trained SVM through analysis of their spheroidal scattering mode coefficients. Previous studies have shown that this approach to classification of similar objects on the basis of object elongation and magnetic permeability is achievable with a high degree of accuracy. Our current study focuses on scatterer volume because the amount of metal present is a key discriminant for field personnel. At the same time, scattering strength (EMI "cross section") depends markedly on type of metal or object shape, as well as volume. Therefore we generated the spheroidal mode coefficients for a population of single spheroids with random shapes, volumes, and metallic composition. Spheroids greater than a certain volume limit were identified as large while the rest were labeled as small. One collection of spheroids was used to train SVM while an independent set was used to validate the accuracy of the SVM classification. Notably, the magnitude of the scattered fields and corresponding scattering coefficients was largely unrelated to object size; nevertheless, the SVM classification in terms of volume for these synthetic objects was shown to be highly accurate. Furthermore, since UXO are often heterogeneous objects, we also generated the spheroidal coefficients from objects composed of two adjacent spheroids of random shape and volume and differing composition. We likewise trained and tested our SVM and were again able to produce predominantly correct classifications.