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13. ABSTRACT (Maximum 200 words)
    This project has involved both numerical simulation of electromagnetic scattering and the associated signal processing for ultra-wideband synthetic aperture radar (SAR) for foliage and ground penetrating radar (FOPEN and GPEN, respectively). With regard to the modeling, we have developed a fast multipole method (FMM) model for electromagnetic scattering from electrically large conducting targets in the presence of a half-space, with application to scattering from surface/subsurface unexploded ordnance (UXO), as well as for scattering from surface vehicles, such as tanks. The FMM simulator is significantly faster than conventional method-of-moments (MoM) solvers, allowing solution of problems that were heretofore intractable. The code has been delivered to the Army Research Laboratory (ARL), and successfully compared with data measured by ARL.
    In addition to this modeling, we have developed hidden Markov model (HMM) automatic target recognition algorithms, applicable to the SAR detection and discrimination of concealed targets. Within the context of the HMM, we have employed a physics based matching pursuits feature parser. This signal processing paradigm has been successfully applied to ARL-measured FOPEN and GPEN data.

14. SUBJECT TERMS
    fast multipole method, hidden Markov model, SAR

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A. Statement of the Problem Studied

Over the three years of funding, significant progress has been made on both signal processing and electromagnetic modeling for FOPEN and GPEN SAR. Considering first the modeling, we have developed a fast multipole method (FMM) simulator for electrically large targets embedded in a half-space region (i.e., for targets in the vicinity of soil). The model is applicable to very general targets, including buried or surface unexploded ordnance (UXO), vehicles and weapons. The model is also applicable for simulating the scattered fields from fiducial targets (trihedrals) placed above soil, these models playing a critical role in the calibration of foliage penetrating (FOPEN) radar systems, such as the ARL BoomSAR. In the future we will apply the FMM model for calibration of the BoomSAR, with this playing a critical role in the development of automatic target recognition algorithms for FOPEN systems.

Concerning signal processing, we have developed a hidden Markov model (HMM) algorithm, which exploits the multi-aspect data available from a synthetic aperture radar (SAR) system. We have applied this algorithm to FOPEN imagery measured by ARL, at Aberdeen Proving Ground. We have demonstrated marked detection performance via HMMs, vis-à-vis the conventional processing applied for this sensor. In the preceding fiscal year we have utilized relatively simple features, to assess the performance of the HMM algorithm itself, without exploiting the most sophisticated features. More recently we have directed significant attention to the development of improved features, via the wave-based matching-pursuits algorithm.

B. Summary of Most Important Results

During the course of this research, two significant developments have occurred. For the first time, the fast multipole method (FMM) has been extended to the case of targets in the presence of a half space. This is a notable escalation in complexity vis-à-vis previous work in this field, which has heretofore been restricted to the case of free-space scattering. Significant work has been undertaken to properly handle the dyadic half-space Green’s function.

The other significant development involves the hidden Markov model (HMM) as applied to the SAR problem. Hidden Markov models are widely applied in speech processing, where they have been very effective. We are the first to expend HMMs to SAR processing, in the context of a physics-based matching-pursuits feature parser. The HMM is an entirely new processing paradigm for this problem class, opening up a new direction of basic research.

C. Refereed Publications


D. Participating personnel

Dr. Norbert Geng (post doc)
Dr. Anders Sullivan (post doc)
Traian Dogaru (PhD earned June 1999)
Mark McClure (PhD earned June 1998)

E. Report of Inventions

None