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Remote Sensing Science - New Concepts and Applications

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Abstract

This is the final report of a one-year, Laboratory-Directed Research and Development (LDRD) project at the Los Alamos National Laboratory (LANL). The science and technology of satellite remote sensing is an emerging interdisciplinary field that is growing rapidly with many global and regional applications requiring quantitative sensing of earth's surface features as well as its atmosphere from space. It is possible today to resolve structures on the earth's surface as small as one meter from space. If this high spatial resolution is coupled with high spectral resolution, instant object identification can also be achieved. To interpret these spectral signatures correctly, it is necessary to perform a computational correction on the satellite imagery that removes the distorting effects of the atmosphere. This project studied such new concepts and applied innovative new approaches in remote sensing science.

1. Background and Research Objectives

The science and technology of satellite remote sensing is an emerging interdisciplinary field that is growing rapidly with many global and regional applications requiring quantitative remote sensing of earth's atmospheric parameters and surface features from space. The Laboratory's core mission of reducing the nuclear danger includes the early detection and discovery of proliferation activities for nuclear weapons and other weapons of mass destruction for which remote sensing from satellites can provide the technical means. It is possible today to resolve structures on the earth's surface as small as one meter from space. If this high spatial resolution is coupled with high spectral resolution per pixel, as for example, with a spectrometer in space, instant object identification may also be achieved. To interpret these spectral signatures (e.g., for plutonium or uranium) correctly, it may be necessary to perform a computational correction on the satellite imagery that removes the distorting effects of the

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atmosphere. These atmospheric corrections require much insight into the radiation transport process and are computationally intensive. This project studied such new concepts to exploit the science and technology in support of the Laboratory's expanding competencies in nonproliferation, environmental monitoring and nuclear waste identification and processing.

2. Importance to LANL's Science and Technology Base and National R&D Needs

This project supports Los Alamos core competencies in earth and environmental systems; theory, modeling, and high performance computing; and nuclear weapons science and technology. It enhances the Laboratory's ability to respond to a broad range of initiatives related to these core competencies.

3. Scientific Approach and Results to Date

A comprehensive scientific review of the field has been carried out to assess the state-of-the-art of satellite remote sensing science as it may be applied to the above-mentioned core competencies. Active (LIDAR) and passive remote sensing techniques, including modeling, have been evaluated and studied in the context of a feasibility analysis.

The main result from this project was the identification of the three most promising emerging scientific subfields in remote sensing: (1) hyperspectral remote-sensing science, (2) laser-assisted remote sensing, and (3) new remote sensing concepts. Initiation of a strategic scientific thrust encompassing these technical components is expected to provide an optimal science and technology base for the expansion of the Laboratory's competencies in nonproliferation and environmental monitoring in support of the Los Alamos core mission to reduce the nuclear danger.

As part of a feasibility study, we performed field experiments with a Fourier-transform interferometer that proved the feasibility of quantitatively detecting the presence and amount of certain gases in a defined plume in the atmosphere when there exists a significant temperature difference between the plume and the ambient temperature.

In active remote-sensing systems the solar illumination of a scene is replaced by a man-made source, preferably a laser beam. However, when laser beams are propagated through a scattering medium like air, random optical path fluctuations comparable to the optical wavelength are generated giving rise to the speckle effect, which is the most severe perturbation in active remote sensing systems. The limitations introduced by the speckle effect degrade or negate the data interpretation. In an attempt to identify remedies for this

perturbation, we developed a new concept that might allow the detection of phase shifts in laser return signals: Fourier-transform heterodyne detection. The technique is based on imaging coherent (laser) light by measuring not only the magnitude of the signal wave front but also its phase. Only a theoretical concept has been developed so far with model calculations that indicate the feasibility of the idea.

New computational models for simulating the transfer of surface reflectance signals through the atmosphere into a satellite detector have also been studied. In particular, the radiosity method has been extended and coupled with existing radiative transfer models. The radiosity method is capable of accurately modeling the radiation field emerging from a three-dimensional surface structure, like a vegetation canopy, to provide input to an atmospheric radiation transport code in the form of a bi-directional reflectance distribution function (BRDF). This allows us to perform coupled radiosity/radiative transfer calculations to simulate and analyze the remote sensing process.

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