SIMULATION OF 3D LASER SYSTEMS

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1. INTRODUCTION

This paper addresses modeling of new optical non-conventional imaging with laser system or ladar (Laser detection and ranging). Optical remote sensing can be divided into passive and active categories based on the source of the light. Passive systems detect natural sources, such as the sun or blackbody radiation due to the temperature of an object. Active systems use a light source, such as a laser (burst illumination laser technique), that can be controlled by the user and tailored for specific applications. The use of an active illuminator boosts the signal-to-noise ratio while relaxing the sensitivity requirements in the receiver. In addition, the availability of near infrared lasers and near infrared focal plane array can make the system practical and cost efficient. The eye-safe property of wavelengths around 1.5 µm is perfectly suited to active laser imagery applications. Laser active systems provide high-resolution day and night imaging. These systems have several distinct technological and practical advantages over passive imaging systems making them attractive alternatives, or at the very least, complementary components to existing infrared imaging technology. An interesting feature of active imagery is the capability to provide depth position of the target with respect to the background. Optical non-conventional imaging explores the advantages of active laser imaging to form a three-dimensional image of the scene. On the other hand, passive visible or infrared sensors collect spatial intensity information but the diffraction limit of the receiver optics gives a physical limit on the effective range of imaging sensors and thermal IR imagers often require cooling for optimum performance for nighttime imaging. 3D ladars can be used for three-dimensional topography, surveillance, robotic vision, enhancing operations in public safety and combat identification because of ability to detect and recognize objects hidden behind porous occluders, such as foliage and camouflage. In this paper, we present the simulation of the 3D ladar sensor including physics based modeling of laser backscattering of complex rough targets, reflectance modeling of porous occluders, development of 3D scenes and reconstruction algorithms for identification.

2. BASIC CONCEPT FOR 3D LASER SYSTEMS

Identifying targets or objects concealed by foliage or camouflage is a critical requirement for operations in public safety, law enforcement and defense. The most promising techniques for these tasks are non-conventional imaging techniques All these techniques utilize unique properties of the target to perform the identification function (geometry, surface, absorption, scattering and depolarization of the electromagnetic waves). Long-wavelength synthetic aperture radar is the traditional approach to identify objects hidden by foliage. But the resolution is limited because the wavelength is several meters and the false alarm rate is high. The ladar sensor uses a short pulse laser with high repetition rate to illuminate the scene. Most of the laser energy is reflected, scattered or absorbed by the foliage, a small amount can reach the target. The ladar captures the time of flight of the scattered pulses to give a function of range, generate a range profile of the target and form a 3D image of the scene. The scene is flood-illuminated with a single laser pulse, the pixels in the detector array measure the time of arrival of the scattered light. This time depends on the range of the imaged target elements. As each pixel of the detector array is coded with range, the ladar system produces a 3D image from a single laser pulse. The sensor which can be airborne or mounted on a moving platform combines several 3D images of the scene from multiple aspects to create a composite image of the scene because a single 3D image can not provide enough information to identify the object. The sensor collects range imagery from which target recognition can be improved. A 3D ladar system requires a short pulse of laser energy on the order of one nanosecond in order to separate targets from overlaid camouflage or forest canopy. Resolving closely spaced returns requires a high-bandwidth detector (about 1GHz) and specific readout electronics. Designing such a detector area to limit the amount of scanning is a challenge. This 3D ladar requires reconstruction algorithm to provide 3D images

3. SYSTEM SIMULATION

This paper describes the simulation of a 3D ladar. The first step of the simulation process is the generation of a scene of interest which consists of many types of objects: buildings, trees, vehicles. The vehicles are often obscured by other objects. A CAD model of the scene is generated. The motion of the platform is simulated by different view points of the CAD model. The second step contains the simulation of the receiver, the transmitter and the optics system. For the transmitter, we define the wavelength, the laser pulse and the temporal convolution of the laser signature of the scene with the laser pulse. For the receiver, we simulate the response of the different types of detectors we can use: detection and false alarm probabilities, detector response function, noise sources. The blurring caused by the optics of the system is simulated. The simulation of the system can also contain scanning schemes.

The third step is the modeling of the electromagnetic scattering from the different objects of the scene. The physics based model, we present in this paper, is designed to provide accurate results but to also include all of the electromagnetic interaction mechanisms. The surface of the different vehicles or hard targets is considered as randomly rough surfaces and we compute the laser signature (laser cross-section) of the vehicles. To model the laser interaction with the randomly rough surface, we use the second order Small-Slope Approximation method. Because the problem, we consider in this paper, is three-dimensional, all the scattering coefficients (coherent and incoherent component of the electromagnetic field) are functions of the azimuth angles, and the cross-polarized terms do not vanish. We define, in this case, the Mueller matrix, which gives all the combinations of the polarization states of the scattered electromagnetic waves. The randomly rough surfaces of the complex object are characterized by electromagnetic parameters (permittivity...) and roughness parameters (standard deviation of rough surface height and autocorrelation function). Our model addresses also transparent structures. With this model, we can obtain high temporal resolved laser backscattering from complex objects. Buildings and trees are modeled by polarized reflectance applied to the different facets generated by the CAD model.

The fourth step contains the absorption and scattering of the laser wave by the components of the atmosphere, the simulation of the atmospheric turbulence effect: speckles, scintillation, beam spreading, beam wandering.

The last step of the simulation contains the development of three-dimensional reconstruction algorithm to obtain a high-resolved three-dimensional image. This computer model can help predict 3D ladar performance and it is used to develop 3D reconstruction algorithm.