SIMULATION OF AN INTEGRATED LADAR SYSTEM

USU LadarSIM Release 3.0

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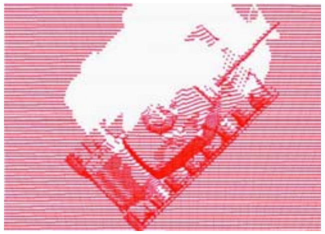
INTRODUCTION

Lidar (Light Detection and Ranging) is a method for determining distance to an object using a laser beam. This distance is defined as the time it takes for a laser pulse to hit an object, reflect and then return to a sensor with the speed of light. Though the theory is similar to radar, using high intensity lasers instead of radio waves can produce higher resolution images.

LadarSIM is a Matlab and Simulink based LADAR system simulator designed and developed by the Center for Advanced Imaging LADAR (CAIL) at Utah State University. It is a tool for general system analysis, error modeling, and specifically assists in the design and development of new LADAR systems.



USU LadarSIM was originally funded by the Naval Air Warfare Center Weapons Division in China Lake, CA. to develop a computer simulation of their LADAR systems. This facilitated data gathering and analysis along with algorithm development. It also became a valuable design tool in predicting the behavior of new LADAR systems being investigated.

Over the years, LadarSIM became more capable and generalized in its function. Due to the most recent improvements in the areas of generic scanning, moving targets and waveform processing LadarSIM can now model a variety LADAR systems of use in a variety of applications.

GENERAL PURPOSE AND FUNCTION

LadarSIM 3.0

In the development of LADAR systems there are two main areas of interest. First, the physical geometric capabilities of the hardware and second, the radiometric performance of the electronics under real world conditions. LadarSIM 3.0 was designed to allow the user to focus on each of these areas independently.

Sensor Path Creation

The creation of the six degree-of-freedom data that defines the sensor platform's position and orientation.

Eye Pointing Criteria Creation

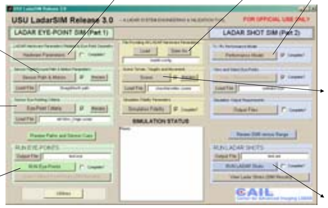
Defines the point of interest in the scene about which the scan is centered. This may be defined in local-level coordinates or in AZ-EL coordinates relative to the optical axis of the sensor.

Eye-Point File

After a geometric simulation has been run, an eye-point file can be created which contains all of the necessary

Hardware Parameters

Define the parameters of the scanner, focal plane array and navigation instruments.



LadarSIM 3.0 Main Interface

Configuration File

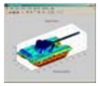
After all of the parameters have been set, they can all be saved in a configuration file for future use.

Performance Model Parameters

All of the environment and transceiver electronics parameters which determine the system performance can be set here or bypassed by selecting a simple model.

Scene Creation

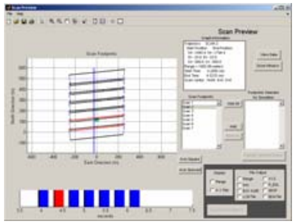
Custom scenes can be developed by selecting the terrain and targets and defining their positions and movement.



Example Target

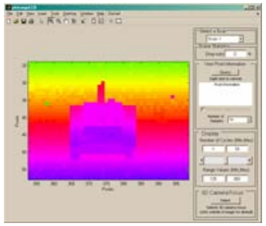
Ladar Shots File

With all of the geometric and radiometric parameters defined, the simulation can be run to generate a ladar shots file simulating the data received from an actual system.



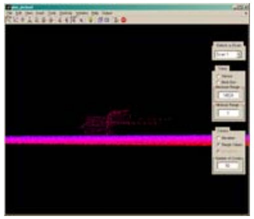
Scan Preview View

When doing a geometric scan this intermediate GUI allows the user to view where the scan footprints lie on the terrain in relation to the targets. The user can then specify which footprints to run a full scan on. This ensures that each scan contains the desired data.



Range Image View

The range-image allows the user to view the range data colored by range values. Each point may be queried to show the x,y,z, range, and other information regarding that point. If desired, the return signal may also be plotted to see what it might look like.



Three-Dimensional Point Cloud

The ladar shots can be visualized in three-dimensions. This viewer allows the user to rotate, zoom and pan around the data set as desired to explore and analyze the results.

RECENT IMPROVEMENTS

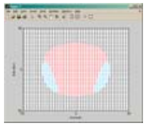
SCANNER MODELING

LadarSIM contains a LADAR scanner model with up to three scan elements allocated with either a steering, stabilization and/or pattern-scanning role. Algorithms automatically generate commands to the scan elements given beam-steering objectives, and the need to compensate for the base motion of the sensor platform.

Scanner dynamics interface

The kinematic model of the mechanisms driving the separate scan elements predicts LADAR scanning performance. Given various dynamic characteristics of the these mechanisms, there exists some flexibility in the partitioning of the steering and stabilization commands. A new partitioning method is implemented that allows for an optimal partition based on the bandwidth capabilities of each mechanism. This approach replaces the alternative of arbitrarily dividing the steering and stabilization, operations between separate scan elements.

Scanner geometry interface



Aperture plot

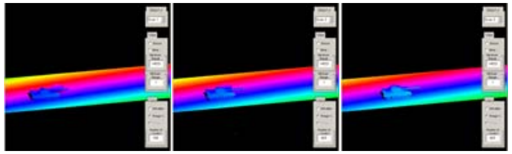
MOVEMENT OF TARGETS AND SENSOR PLATFORM

Target and sensor platform motion can be simulated. The moving objects may be forced to follow the local terrain and rotate to be tangent to it. Additionally, an extra elevation offset above the ground may be applied in this mode. Motion due to turbulence may be also be added to moving objects, and high-frequency, low-amplitude jitter may be added to the sensor platform.

Target motion user interface

Six degree-of-freedom motion is defined by path segment selection and definition on the part of the user so that objects may turn, pitch, spin, and move forward with constant acceleration.

Target motion may be used to model target "stretching" seen with fast-moving targets and/or slow-scanning motion.

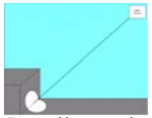


Point cloud images showing target motion

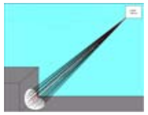
WAVEFORM PROCESSING

Modeling Return Signals

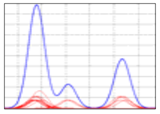
By over-sampling inside the area of a ladar beam footprint, an approximate return signal can be constructed by summing all of the scaled return pulses. This give insight into phenomena that occur in and around edges.



Diverged beam on edge



Over-sampled beam footprint

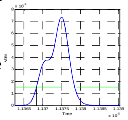


Example Return Signal

Detection Methods

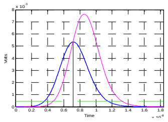
Leading Edge

A detection is declared for the point at which the signal exceeds a set voltage threshold.



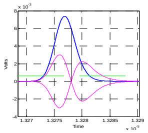
Constant Fraction

A detection is declared for the point at which a delayed version of the pulse intersects with a fractional version of itself.



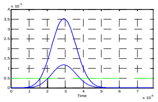
Crossover (Derivative)

A detection is declared for the point at which the derivative of the pulse and its negative crossover.



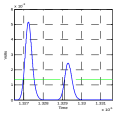
Walk Error

Due to varying intensities of return signal waveforms, a phenomena called walk error can be seen using the leading edge method. As seen in the figure different range values are determined from different signal amplitudes.



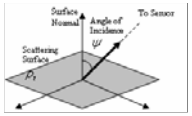
Multiple Returns

With waveform processing implemented into the simulation, LadarSIM can model and plot multiple return pulses. This is a common occurrence in actual LADAR systems and is valuable in studying objects beneath trees or shrubbery.



BRDF

A Bidirectional Reflectance Distribution Function has been implemented to more accurately model the amount of energy reflected by various materials at different incident angles.



VISSTA

Vehicle Integrated Sensor Suite for Targeting Applications

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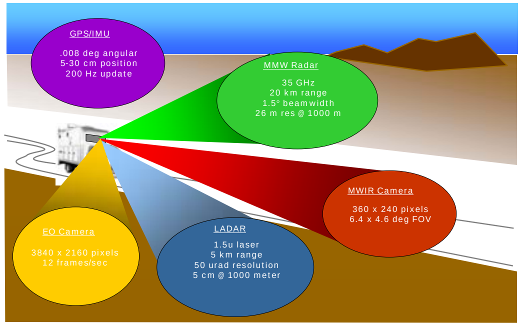
OVERVIEW

The goal of the VISSTA program is to provide the U.S. Navy with the ability to simultaneously collect data from a variety of co-boresighted sensors mounted on a moving platform. Sensors include a millimeter wave radar, an in-house developed ladar with an integrated EO (color) camera, and a mid-wave infrared camera.

The VISSTA facility will explore multi-sensor performance in various scene conditions (vegetation, obscurants, rugged terrain, etc.), atmospheric conditions (fog, haze, etc.), and fields-of-view. It will also allow each sensor's strengths and weaknesses in the detection, recognition and identification roles to be explored.

This project is a joint effort of Utah State University's Center for Advanced Imaging Ladar and Space Dynamics Laboratory and the Naval Air Warfare Center, China Lake, California.



VEHICLE INTEGRATED SENSOR SUITE

Optical Sensor Suite

for sensor fusion studies

Sensors include the eye-safe ladar test-bed (ELT) instrument, a millimeter wave radar, and an infrared camera. The ELT also includes an imager for visible wavelengths called a Texel Camera. These can all be pointed and operated on the van platform.



Custom Van Body

electronics rack, control station and creature comforts

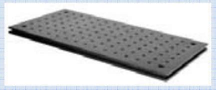
The rack contains the electronic equipment used for control of the sensor bench and suite of sensors. The electronics are shock resistant and are cooled by AC equipment. A UPS allows a graceful shut down in the event of a power failure. Creature comforts including a microwave and fridge make long stints of data collection more bearable.

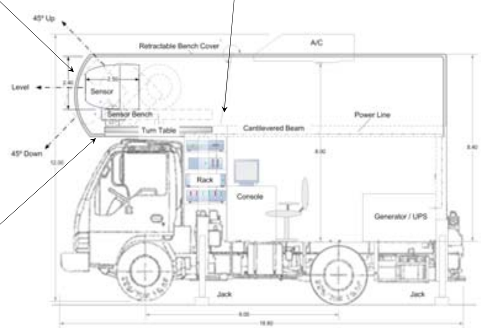


Sensor Bench

controls and measures gross sensor orientation and position

A manually positioned motorized platform controls the orientation of the suite of sensors relative to the van. A precision GPS/IMU position and orientation system senses the motion of the bench and allows geopositioning of acquired data.



EYESAFE LADAR TESTBED

Ball Joint Gimbal Mirror

coarse sensor pointing

The Ball Joint Gimbal Mirror steers the laser beam toward the area of interest. Compared to the fine steering mirror, it has a greater range of motion, moves slower, and increments at a larger resolution.


Texel Camera

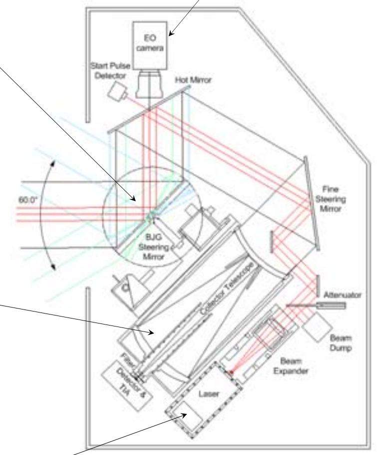
high resolution color imagery

A co-boresighted color camera takes high-resolution CMOS digital images of the scene. The pixels of the image are precisely aligned with the ladar shots. This results in on-the-fly generation of three-dimensional color images composed of texels.


Telescope Receiver

collects reflecting photons

The laser pulse is reflected off of the target, collected in a telescope and focused on a photodiode detector. The detector converts the pulse to an electronic signal that is digitized and stored. The full waveform of the signal is collected enabling experimentation with a variety of techniques for accurately measuring the range to target.



Laser Transmitter

sends photons to the target

Laser pulses are emitted 10,000 to 100,000 times per second by a laser head. The photons in each pulse are bounced off of the target and returned to the telescope receiver for detection and measurement.


Fine Steering Mirror

fine raster scanning

The Fine Steering Mirror (FSM) scans the laser energy in a raster pattern which is then steered by the Ball Joint Gimbal Mirror. The FSM has a small range of motion but can move fast and accurately.