DIRSIG
A complex graphics application for modeling a variety of remote image acquisition systems

What does a vehicle look like?
• The truck leaves a shadow on the ground
  – The ground is cooler because it has been in the shade.
• You can see a reflection of the hot engine in the asphalt as it drives by.

DIRSIG: Applicable Areas
• Sensor Prototyping
  – Construct and test a new sensor in a virtual environment
  – Evaluate design trades
  – Produce example products for customers
• Algorithm Testing
  – Decrease amount expensive field collections
  – Control all the image formation variables
  – Per-pixel truth allows for better evaluation
• Algorithm Training
  – Predict observations that may be found in images to pre-train complex algorithms.
• Analyst Training
  – Create custom training examples
  – Test the sensitivity of the analyst to phenomenology
  – Provide a tool to hypothesis about the nature of phenomenology

DIRSIG Short Course

Radiometry Submodel:
Radiation Sources

1 Directly Reflected
2 Background Scattered
3 Skylight
4 Scattered by Atmosphere
5 Target
6 Background Reflected by Target
7 Atmosphere Reflected by Target
8 Atmosphere

Simulated Data Products
– Subpixel Target Detection
– Subpixel Target Truth
– Subpixel Target Intensity
– Radiance Intensity
– Image Intensity Light Imagery

Simulated Data Exploitation
– Simulation of observed
– Simulation of reality
– Simulation of atmosphere

Thermal
Model

Sensor

Target

Background

Atmosphere

Range Gate

Polarized/Unpolarized

Broadband, multi

hyper, ultra

spectral imagery

Target and background
databases with spatial and
spectral variability (clutter)

Fully spectral radiation
propagation

Simulated Data

Exploitation

Products

– Target
– Foreground
– Background
– Shadow
– Shadow of Target
– Target and Background
– Shadow of Target
– Background Reflected
– Directly Reflected

PRISM/Muse

Generic models
via DXF/OBJ import
BRDFs, Emissivities

Scattering Phase Functions

Nearly specular

Visible Region

Daytime

Visible Region

Nighttime

Thermal Region

Nighttime

Simulated Data from Rhino3D

Tree Models from Tree Pro

Facetized Terrain from DEM/DTED

Terrain Attribute Maps

Target models from PRISM/Muese

Generic models
via DXF/OBJ import
BRDFs, Emissivities

Scattering Phase Functions

Nearly specular
 radiant "shading" beneath truck and internal power source (engine) ____________________________
resulting from utilizing solar shadowing histories ____________________________

Thermal Simulation: Rochester NY in Winter at Night

Plume Modeling: Example

• A simulation of a gas plume release at the Nevada Test Site. The actual plume release was used to validate our simulation.

• If the simulation is accurate, then costly and environmentally unfriendly field releases can be avoided in the future.
Gas Absorption Database

- Acquired from EPA Laboratory Measurements
- Database ranges from 2.2 - 25 mm at 0.25 cm⁻¹ resolution

Methyl Chloride (CH₃Cl)

3 meter path length at 500 ppm, 298 K

Gas Cloud: Temporal Behavior

- This movie shows the drift and expansion of the gas cloud over the terrain
  - From 25 ms to 600 ms after release

Spectral Profiles: Large Payload

20 kg release, 1500 sec after detonation, against background

Terrain Background Sky Background

Low-Light Images

Daytime Nighttime

Low-Light Images

Low-Light Images
Low-Light Simulation:
Low-Light and Thermal Image Examples

Simulation time = 0200 hours
New Moon Conditions

Low-Light Visible Radiance
Thermal Radiance

Low-Light Simulation:
Fused Image Example

Image fusion of simulated low-light and thermal imagery

Line Scanner:
Optical Geometry

Sensor Modeling:
Geometric Characteristics

INSTRUMENT {
  TYPE = FRAMING_ARRAY
}
• Radial relief displacement

Sensor Modeling:
Geometric Characteristics

INSTRUMENT {
  TYPE = PUSHBROOM_SCANNER
}
• Cross-track relief displacement
  • No tangential distortion

Sensor Modeling:
Geometric Characteristics

INSTRUMENT {
  TYPE = LINE_SCANNER
}
• Cross-track relief displacement
  • Tangential distortion
Scanning Sensors:
Sources of Geometric Distortion

Sensor Modeling:
Geometric Characteristics

Applications and Phenomenology
- Loading Problems
  - Sky, cloud and tree shine problems
- Cavity/Calibration Problems
  - Cavity radiance effects from chambers/cavities with non-ideal surface properties.
- Polarization
  - Full-spectral polarimetric modeling capability
- Water/Littoral
  - In-water scattering/absorption to understand adjacent effects.
- Plume Detection
  - Provide a framework to evaluate instrument designs.
  - Provide a source of data for rigorously testing algorithms.
  - Truth is known for every pixel.

The Cooling Tower Problem
- Problem:
  - Estimate the cooling load (water temperature) from observed radiances.
  - The observed radiance is a combination of direct emission from the viewed surface and reflected emission from adjacent surfaces.
  - To evaluate the expected variations in the tower leaving radiance, a model of the tower geometry can be constructed.
  - The individual surfaces within the tower can be attributed with unique emissivity and reflectance properties.
  - DIRSIG can provide insight into the effect of uncertainties on the tower leaving radiance.
  - Uncertainty in water temperature.
  - Uncertainty in surface temperatures.
  - Uncertainty in surface emissivity.
  - Uncertainty in internal construction.

Cooling Tower Simulation
- DIRSIG Simulation using precomputed surface temperatures.
  - Cannot directly see the warm water in the tower
  - All multiple bounce
  - Note apparent temperature gradients near fan hub and shroud walls.
  - Small holes are from sampling small grooves in the top "deck"
  - Will be smoothed with PSF

Scene Overview
- Candidate site
  - Irondequoit NY
  - North-east corner of city
- Data Availability
  - Field Collections
    - Close proximity allows for easy and frequent ground collects.
  - Image Collections
    - MS
    - IKONOS
    - AVIRIS
    - MTI
    - Hyperion
    - Kodak CIBR

Page 5
MegaScene #1: Tile #1

A channel from a thermal infrared hyperspectral simulation featuring strong and weak gas plumes.

MicroScene 1

Near-IR (830 nm) channel from a 70-channel simulation of the RIT Modular Imaging Spectrometer Instrument (MISI) imaging a camouflage and concealment experiment.

Camouflage Level of Detail

Digital photo at real scene

Polarization States

- Polarization due to relationships between the magnitude and phase of the orthogonal electric field components
  - Random
  - Linear
  - Circular
  - Elliptical
“Real Material” Reflectance

- Real materials are complex, with two basic reflectance components
  - Surface
  - Volume
- Surface reflectance
  - Highly color neutral
- Volume reflectance →
  - Color
- Umm's effect: DOP and brightness inversely proportional

Demonstration of Polarization

Vertically Polarized Filter
Horizontally Polarized Filter

Imaging System Demonstration: "Magic 8-ball"

AFRL Polarimetric Images

S0
S1
S2
DOLP

First DIRSIG Polarimetric Images

S0
S1
S2
DOLP

Army TARDEC Collections

This work conducted by
Grant Gerhart
at Army TARDEC

COTS Polarized Imaging System

Visualization of Stokes Parameters

Using New Sensor/Platform Model
A simple, polarized scene simulation
- Vehicle BRDF modeled using AFRL's multi-parameter, polarized BRDF model.
- Grass modeled using RIT's Shell Background model.
- No sensor noise or MTF effects.

Sample Imagery (Color Renderings)
- Color Images: Red (500: 650nm), Green (500: 550nm); Blue (500: 450nm)
- 3 Viewing Angles (Forward, Side and Backscatter)

Sample Imagery (DOLP)
- DOLP Images (650nm)
- 3 Viewing Angles (Forward, Side and Backscatter)

The scene is stimulated with a pulsed beam that has a spatial, spectral and temporal shape.
- The goal is to produce a simulation environment that can simulate as much physics as possible and provide a tool for design trade studies and algorithm testing.

LIDAR at MicroScene1

Topographical LIDAR Demo
Camouflaged Vehicle Simulation

CAD Models

LEBAH Plate Cubes

Height Truth Imagery

Top of hat

Spreaders

Humvee roof

Remote-Infrared

Remote shadow

Time

RIT Topographic Processing

T-72 Tank

HMVV

The Benefits of First Principles Based Modeling