The Incorporation of Atmospheric Variability into DIRSIG

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Talk Structure

• Background: Overview of DIRSIG
  – Image Rendering
  – Role of the ADB

• Atmospheric Modeling Issues and solutions
  – Geometry
  – Inhomogeneities

• Conclusions and Future Directions
Justification: Why Model?

- SIG is used to test hyperspectral algorithms
  - by controlling atmospheric conditions we can know ‘ground truth’ absolutely

- Real atmospheric variability leads to errors in these algorithms, and must be accounted for.
Image Rendering in DIRSIG

(DIRS Synthetic Image Generation tool)

Input

Scene parameters (objects, geometry, atmospheric characteristics, …)

DIRSIG

Atmospherics

Sensor-reaching Radiance

Final result
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Scene Geometry

Illustration of the ray-tracing process for a simple framing camera.
DIRSIG Overview: Image Rendering

- **Illumination Sources:** For a given pixel, calculate energy reaching the ground.
DIRSIG Overview: Image Rendering

- **Scattering and transmission effects:** DIRSIG Calculates path radiance and transmission from target to sensor.
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How does DIRSIG calculate the atmospheric values?

• **Uses MODTRAN**
  - Managed and maintained by the Air Force’s Geophysics Laboratory at Hanscom AFB.
  - Predicts solar and lunar irradiance, path transmission, scattering, and emission.
  - Produces solutions in the spectral region from 40,000 cm⁻¹ (0.25 µm) to 400 cm⁻¹ (25 µm). Maximum resolution of 1* cm⁻¹.

• **Creates and uses the Atmospheric Database (ADB)**
  - An LUT of path radiances and transmissions for various geometries.
Current ADB Structure

• Two major components
  – The “sky” or “downwelled” paths
    » Sky radiance for the hemisphere
    » Currently a function of zenith and azimuth
  – The “sensor” or “upwelled” paths
    » Path radiance and transmission for the field-of-view of the sensor.
    » Currently a function of zenith only.
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Geometric Issues

• Issues to address:
  – Non-zero Altitude (scaling) problem
  – Undersampling of the upwelling radiance (no azimuthal variation)
Existing Geometric problem: Altitude Problem

- **Non-Zero Altitude:**
  - DIRSIG scales the entire atmosphere to new length when encountering a non-zero altitude.
  - Includes ALL layers of atmosphere, regardless of altitude of object’s altitude
  - These lower layers effect path radiance and transmission exponentially more than higher layers
Altitude Interpolation Experiment

- Sample the atmosphere at multiple altitudes

Experiment:
- compared cumulative transmission and upwelled radiance between DIRSIG and MODTRAN methods of looking at various altitudes
- goal: to determine location and severity of altitude problem
Typical Results

• Sensor at 100km

**Transmission (sensor at 100 km)**

- **MODTRAN**
- **DIRSIG**

**Upwelled Radiance (sensor at 100 km)**

- **MODTRAN**
- **DIRSIG**
Upwelled Radiance (sensor at 100 km) w/sample at 1 km

Sampling at 1km

Sample here (0 km)
Sample here (1 km)
Sample here (2 km)
Sample here (3 km)

Interpolate path radiance and transmission from top of the object
Interpolate path upwelled radiance and transmission from top of the object

Digital Imaging and Remote Sensing Laboratory
Azimuthal Sampling

**Current Method**

**Proposed Method**

**Corresponding Upwelled radiance map**
Angular Interpolation Experiment

- Examples: (overhead view of LUT structure, only one altitude shown)

- 2 zenith angles
- 2 azimuth angles

- 4 zenith angles
- 4 azimuth angles
Look Angle to be Examined

- **Angle selection guidelines:**
  - Chose look angle to avoid interpolation points as much as possible. (Looking at an interpolator point would yield a difference \(\sim 0\))
  - Made sure angle was within the range of the LUT
Experiment Conclusions/Recommendations

- 8 zeniths and 8 azimuths optimal for most of the sky
- More may be needed about the solar axis

![Graphs showing maximum and average difference as a % of MODTRAN vs. number of angles.](image-url)
Adding in the results from the altitude experiment.

- Must have 2 altitudes
  - solves altitude (scaling) issue

- Must have 8 zenith and 8 azimuth angles to sample upwelled radiance
  - Balance between accuracy and time expenditure
Recap: This structure will correct the altitude problem as well as azimuthally sampling the upwelling radiance.
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Atmospheric Variability

- Heavy aerosols
- Clear sky
- Light water vapor
- Heavy water vapor
Atmospheric Variability

- Q: How do we incorporate these inhomogeneities as it relates to rendering?

- 1: Create spatial maps of atmospheric species

- 2: Include multiple Atmospheric Databases
Mappings
What do they do?

• “Maps” properties to a facet or set of facets in the scene.
  – Change absorption / transmittance properties
  – Change densities
  – Directly supply temperature data.
Multiple ADB Procedure

• Create a series of Atmospheric Databases
  – One for each species of inhomogeneity (water vapor, aerosols, etc…)

• DIRSIG will reference these while rendering
**Rendering**

- Path A: no water
- Path B: low water
- Path C: high water

**Set of ADBs (1 for each density)**

- Path C: 0.5 g/cm³
- Path B: 0.1 g/cm³
- Path A: 0.0 g/cm³

Water vapor density
Conclusions and Recommendations

• Sampling the atmosphere at multiple altitudes will solve the scaling issues.

• Adding azimuthal variation will allow us to more completely sample the atmosphere.

• Creating multiple ADBs will allow us to model atmospheric variation.
My future work

- Further testing of geometric corrections with a more dynamic atmosphere.
- Verification of interpolation of atmospheric species
- Test scenes will full DIRSIG image rendering to target these effects
Future Directions: beyond my research

- More robust downwelled sampling method

- Using an outside model to generate realistic variabilities (Models3, EPA models...) and incorporating them into DIRSIG.

- Cloud issues such as surface effects and reflectivity.