Scientific Challenges in Information Retrieval from Earth Observation Imagery

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Model of the Earth Observation Remote Sensing End-to-End Information Channel

Sensor System

Scene (reality) Observable Phenomena

Sensor subsystem

Data Package Raw or calibrated

Physical linkages to signatures

Analysis System

Pre-processing

Decision Criteria Image interpretation Classification

Image processing Analysis Algorithms

Delivery System

Archive & Distribution

Search Distributed archives

Information products of socio/economic, security, and/or scientific merit in the marketplace

Inputs

Outputs

Outcomes

Remote sensing analysis
Outcomes from EO imagery are used by decision makers for

- Weather forecasts
- Establishment of protocols regulating the emission of greenhouse gases
- Selection of a corridor for a new highway
- Yield of agricultural products
Where is the Image Information?

Time changes
High spatial resolution EO imagery

- EO content in high resolution scales results in objects (semantics)
Low spatial resolution EO imagery

- EO content in low resolution scales results in parameters (geophysical)
SAR image time series
12 images every 11 days

- Forest
- Agriculture
- Grassland
- Urban
Space-based Observation Platforms

- Multiple dimensional challenges
  - Hyper-Spectral
  - Hyper-Spatial
  - Hyper-Temporal
  - Hyper-Sensors
Challenge – Hyper-Spectral

- Physical basis for spectral properties
  - Photons will interact with the target on a molecular scale.
- Interdisciplinary research is required to develop the knowledge base for deriving the information content from EM radiation interaction with targets.

Collaborations
- Accelerate research process
- Maximize knowledge discovery
- Minimize data handling
- Contribute to both fields

Domain Experts

Remote Sensing Analyst

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Domain Expertise Example

Leaf pigments
Cell structure
Leaf water content
Red edge

ABSORPTION SPECTRA FOR CHLOROPHYLLS A AND B

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Where is the information in the signal?

Wavelets

Haar

Coiflet-1
Challenge – Hyper-Spatial Resolution

Zoysia Grass

Rridged Soil - Marietta fine sandy loam

Disked Soil - Leeper silty clay loam

Long Term Fallow Soil - Leeper silty clay loam

Wet Leeper silty clay loam

Standing Water
Surface Roughness

Two different soil types and grass from North Farm & Ramsey Bottom.
Impacts of Rain or Irrigation

Soil – Dry, wet, standing water
Electromagnetic Scattering (BRDF)

Ridged soil.

![Graph showing Electromagnetic Scattering (BRDF) with Ridged soil.](image)
3-D Visualization of Lambertian Surface - Zoysia Grass
3-D Visualization of Hot Spot - Ridged Soil
Challenge – Hyper-Temporal

USDA Ultraviolet Radiation Network: MS01 September 2000

- Total Horizontal Radiation
- Diffuse Radiation
- Direct Beam Radiation
Challenge – Hyper-Sensors

The A-Train

- **OMI** – absorbing aerosol
- **aerosol profiles, cloud tops, drizzle**
- **PARASOL** 1:31:15
  - polarization, multi-angle
- **CALIPSO** 1:31:15
- **CloudSat** 1:31
  - thick clouds
- **Aqua** 1:30
- **OCO** 1:15
- **CERES**: TCA fluxes
- **MODIS**: cloud \( r_{e, t} \)
- **AMSR**: LWP
- \( O_2 A \)-band
Image Time Series

Optical data
- discontinuous (clouds)

SAR data
- continuous

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<th>mid res</th>
<th>high res</th>
<th>coherent</th>
<th>incoherent</th>
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<th>classification maps</th>
<th>surface phenomena</th>
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<td>weather</td>
<td>change detection</td>
<td>DEMs, velocities, targets, classification</td>
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Information Content in EO Images

Panchromatic optical images (brightness, texture, objects, analysis of pixels and patches, time series)

Multispectral optical images (channel differences)

Hyperspectral optical images (signatures, endmembers)

SAR images (brightness, scatterers, texture, objects, coherence, analysis of pixels or patches, time series)

Polarized SAR images (scattering characteristics)

InSAR data (e.g., phases, phase gradients)

PolInSAR data (combined features)

Interferometry data (3D, displacements)

Input data to be handled:
- Image data products comprising pixels and metadata
- Supplementary data including text and data from geographical information systems (GIS)

Conversion into feature space:
- Handling pixels or patches
- Sensor-dependent feature extraction
- Data cleaning (e.g., removal of artifacts)

Clustering and grouping:
- Grouping color, texture, time
- Exploiting hidden information (“latency”)
- Strategy: handling and statistics of “visual words”

User driven interactions:
- Semantic annotation by “linguistic words”
- Active learning
Results of a Semantic Query
Semantic Class: Agriculture
EO based solutions will require expertise and/or data sources from globally distributed resources.

These same solutions may require processing of data into information from specific resources.

How do I bring together geospatially diverse resources to facilitate sharing and knowledge discovery?

How do I mine data from a variety of sources (sensors, databases, images) into information products and actionable intelligence?