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Sandia National Laboratories

Geospatial-Temporal Remote Sensing Analysis Using Semantic Graphs

Project Number (SL12-DeltaSpaceTime-PD06)

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Project goal: Develop and demonstrate geospatial-temporal semantic graph algorithms to enable detection of proliferation-related activities based on wide-area remote sensing.

Introduction

- A geospatial-temporal graph is a graph in which the nodes have geo-spatial and temporal attributes and the edges define geo-spatial and temporal relationships between nodes.
- Represent targets as sub-graphs ("templates").
- Automated search via graph filter, sub-graph isomorphism.
- Designed to enable region-scale search.

Results

- Streaming graph construction algorithm implemented.
- SQL graph representation and storage implemented.
- Graph representing multi-modality data implemented.
- GIS compatible output representations implemented.
- Initial construction of temporal graph with multiple time periods implemented; change analysis still in progress.
- Data provenance representation implemented.
- Multi-time period data identified and collected.
- Supporting provenance data collected.
- Collaboration with NA-22 benchmark imagery project started.

Next Steps

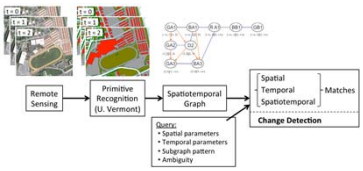
- Finish graph construction, with change analysis.
- Subgraph isomorphism, partial match, other search algorithms.
- Implement algorithms to use data provenance in search.
- Focus on facility identification and characterization.
- Perform various searches on resulting constructed graph.
- Statistical analysis/confidence (in collaboration with external project).

Conclusions & Relevance to Program Objectives

- We anticipate finding facilities in remote sensing data covering wide, complex areas.
- We anticipate that feature-based change analysis will enable substantially improved automatic change detection and temporal analysis.
- We anticipate effective search of multi-modality data.
- Achievements to date have significantly reduced risk.

Methods

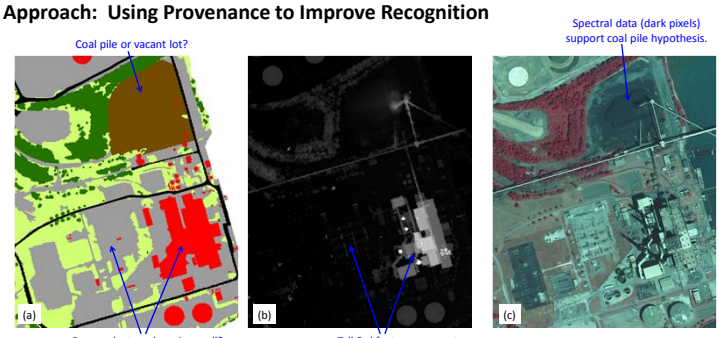
Approach: Computation Flow



Geospatial-temporal graph analysis:

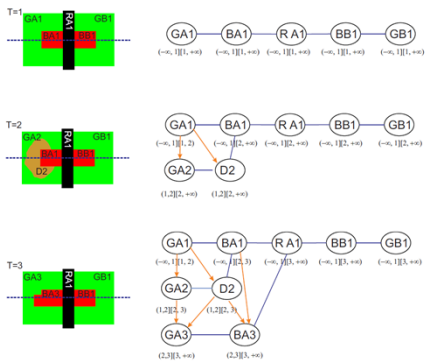
- Sensor data captured from multiple times.
- Spatiotemporal graph generation.
- Graph search types:
  - Pure spatial: Find all power plants.
  - Pure temporal: Find all changes.
  - Spatiotemporal: Find all power plants that have changed.
  - Patterns: Identify common regions (residential, industrial…).
  - Anomalies: Find unexpected features.

Approach: Using Provenance to Improve Recognition



Example: Herbert A. Wagner Generating Station
- Difficult to recognize using landcover data (a) alone.
- Recognition augmented by focused analysis of provenance height data (b) and raw imagery (c).
- Note: Automatic search not implemented yet.

Approach: Geospatial-Temporal Graph Construction



@time 1:
- Initial observation

@time 2:
- new node: GA2
  - *change edge* from GA1
- new node: D2
  - *change edge* from GA1

@time 3:
- new node: GA3
  - *change edge* from GA2, D2
- new node: BA3
  - *change edge* from D2, BA1

Feature: Grass
Feature: Building
Feature: Roads
Feature: Dirt
Edge: Adjacency
Edge: Change

$(t_{last\_absent}, t_{first\_seen}][t_{last\_seen}, t_{first\_absent})$

- t_{last_absent} : *oldest* time feature is observed absent
- t_{first_seen} : *first* time feature observed
- t_{last_seen} : *most recent* time feature observed
- t_{first_absent} : *first* time feature is observed absent

Temporal information is updated for features on each observation.

Planned Sample Query: Searching for all nodes with $t_{first\_absent}=+\infty$ would return the *most recent* world state.

Planned Sample Query: Searching for the reverse transitive closure of change edges associated with a given node(s) would return the history of changes leading up to current node.

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