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Defense Nuclear Nonproliferation Research and Development

Nuclear Weaponization and Material Production

Detection Review Meeting

(MPD 2014)

Oak Ridge, TN

MPD Objective B, Requirement c

NA-22 Program Manager: Jim Pelz

Change Detection via Geospatial Graphs

Randy C. Brost, Ph.D.

Sandia National Laboratories

May 1, 2014

**PROPER ADC CLASSIFICATION BOX
(Overall Presentation)**

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Name/Org: **Mark D. RIntoul**

Date: **3/24/2014**

April 29 – May 1, 2014

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Mission Goals:

- **Identify clandestine weapons facilities.**

Project Objective:

- **Develop geospatial-temporal semantic graphs for automatic wide-area search and change analysis.**

Result Summary:

- **Designed geospatial-temporal graph (GSTG) representation encoding time.**
- **Implemented GSTG construction, including automatic change analysis.**
- **Implemented automatic search, finding change over wide areas.**
- **Automatic search for industrial facilities, such as power plants and refineries.**

GeoGraphy team:

- Randy Brost
- Will McLendon
- Ojas Parekh
- David Perkins
- Danny Rintoul
- David Strip
- Diane Suh

- • **Motivation.**
- **Basic concepts.**
 - **Results.**
 - **Summary.**

Motivation:

- Manually scanning wide areas is tedious and error-prone.
- Change detection and temporal reasoning are even more difficult.

General approach:

- Automatically present candidates for analyst review.
- Geospatial-temporal semantic graphs allow semantic reasoning.

Anticipated value:

- Finding items which might have been overlooked.
- Maximizing use of analyst expertise.

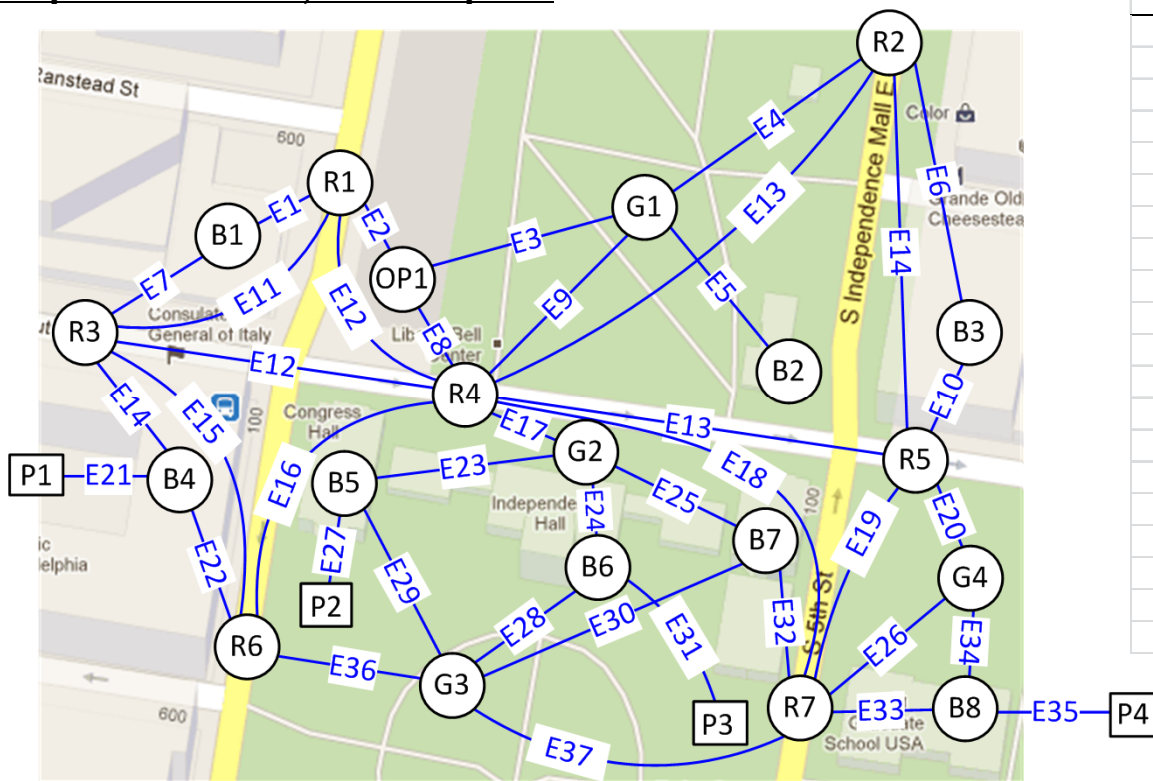


Types of searches:

- **Geospatial:**
 - Find all power plants.
- **Temporal:**
 - Find all changes.
- **Geospatial-temporal:**
 - Find all power plants that changed.
- **Multi-modality:**
 - Find new construction near points of known interest.
 - Find all power plants with unusual emissions.
- **Activity:**
 - Do any industrial facilities have activity matching patterns of interest?

- Motivation.
- • Basic concepts.
- Results.
- Summary.

Independence Hall, Philadelphia:



Point node table:

id	Name	Address	Latitude	Longitude
P1	Consulate of Italy	150 S. Independence Mall West #1026	-75.14895	39.94884
P2	Congress Hall	41 N 6th Street	-75.14920	39.94899
P3	Independence Hall	520 Chestnut Street	-75.15000	39.94889
P4	Graduate School USA	150 S. Independence Mall West #674	-75.15090	39.94819

Region node table:

id	type	area	centroid x	centroid y
B1	building	3200	-75.14900	39.94939
R1	road	1800	-75.14910	39.94949
OP1	paved	4700	-75.14935	39.94934
G1	grass	22000	-75.15010	39.94944
R2	road	1900	-75.15060	39.94999
R3	road	1100	-75.14885	39.94934
R4	road	2200	-75.14980	39.94924
B2	building	780	-75.15045	39.94931
B3	building	6000	-75.15075	39.94944
B4	building	12000	-75.14895	39.94884
B5	building	2100	-75.14920	39.94899
G2	grass	7700	-75.14990	39.94906
R5	road	870	-75.15065	39.94896
B6	building	2000	-75.15000	39.94889
B7	building	3150	-75.15040	39.94884
G4	grass	15300	-75.15080	39.94869
R6	road	1970	-75.14905	39.94844
G3	grass	25000	-75.14960	39.94829
R7	road	1810	-75.15050	39.94834
B8	building	2700	-75.15090	39.94819

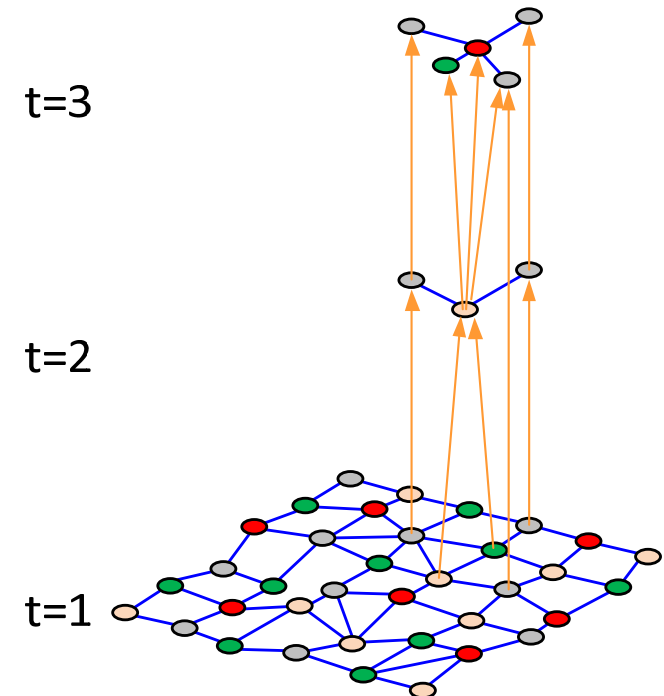
Edge table:

edge_id	node_1	node_2
E1	B1	R1
E2	R1	OP1
E3	OP1	G1
E4	G1	R2
E5	G1	B2
E6	R2	B3
E7	R3	B1
E8	OP1	R4
E9	R4	G1
.	.	.
.	.	.
.	.	.

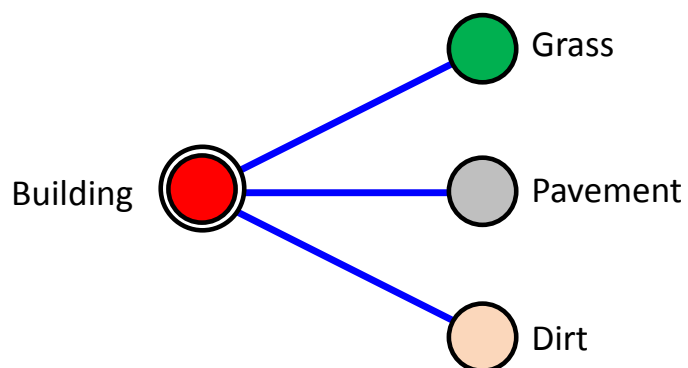
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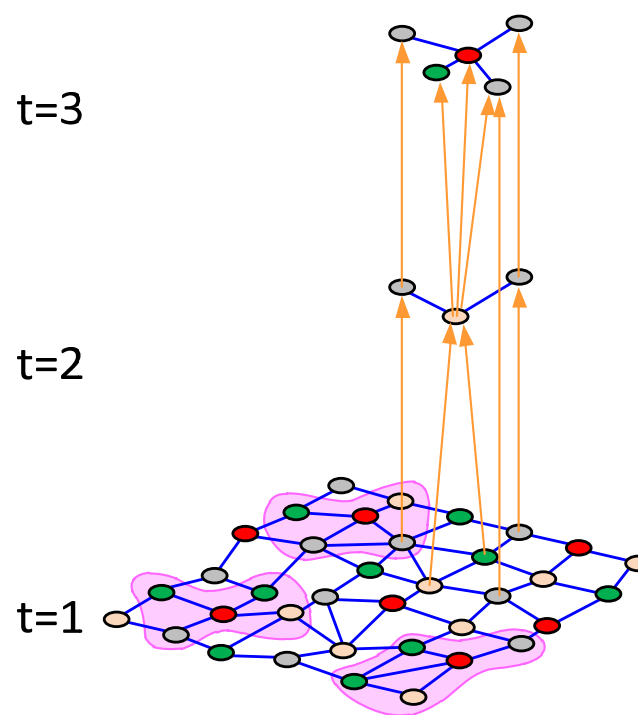
- **Encode change:**
 - Node attributes include duration seen.
 - Only construct new nodes for changes.
 - “Changed-to” arcs encode time evolution.
 - Graph complexity focuses on change areas.



- A signature encodes a desired question.
- Example: “Where are buildings with nearby grass, pavement, and dirt?”

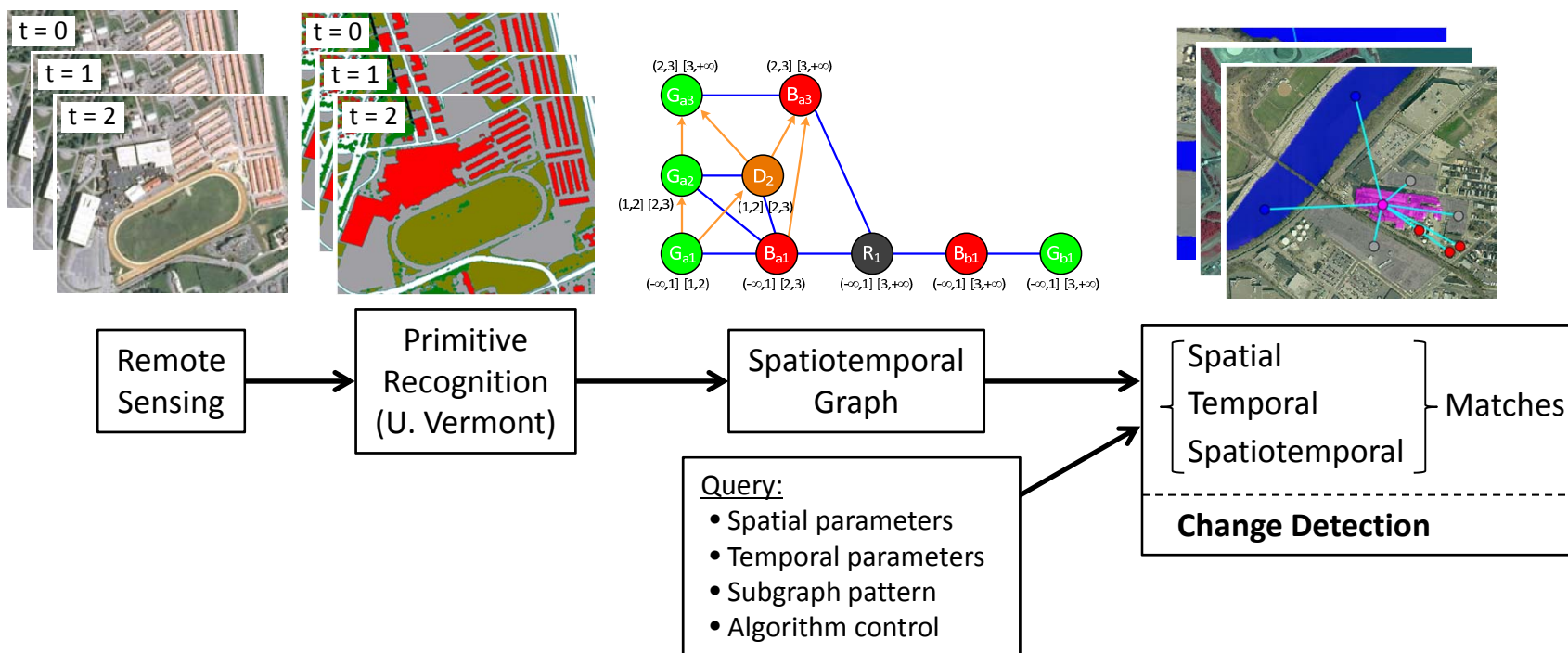


Query Template



Search Results

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- **Motivation.**
- **Basic concepts.**
- **Results:**
 - – Data.
 - Geospatial search.
 - Geospatial-temporal search.
- **Summary.**

Data sets in hand:

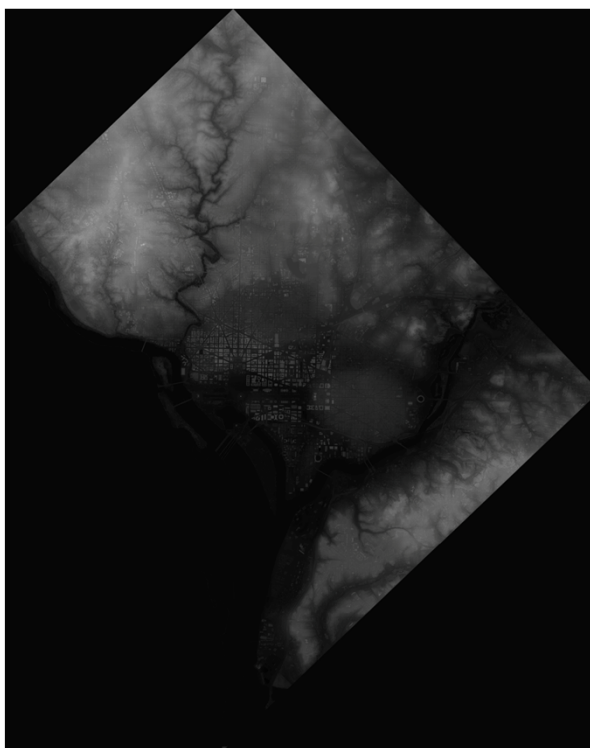
- **Single time:**
 - Anne Arundel County.
 - Greater Baltimore area.
- **Two-time:**
 - Washington, DC.
 - Philadelphia (2nd-generation pre-processing).
- **The above include provenance data (imagery, LiDAR, GIS).**

...Over 180 billion pixels total.
(Typically 1 m resolution or finer.)

Washington, DC example:



4-Band (RGB+IR) Imagery



Digital Surface Model, from LiDAR



GIS Road Polygons

Data provided by Jarlath O'Neil-Dunne at the University of Vermont Spatial Analysis Lab.

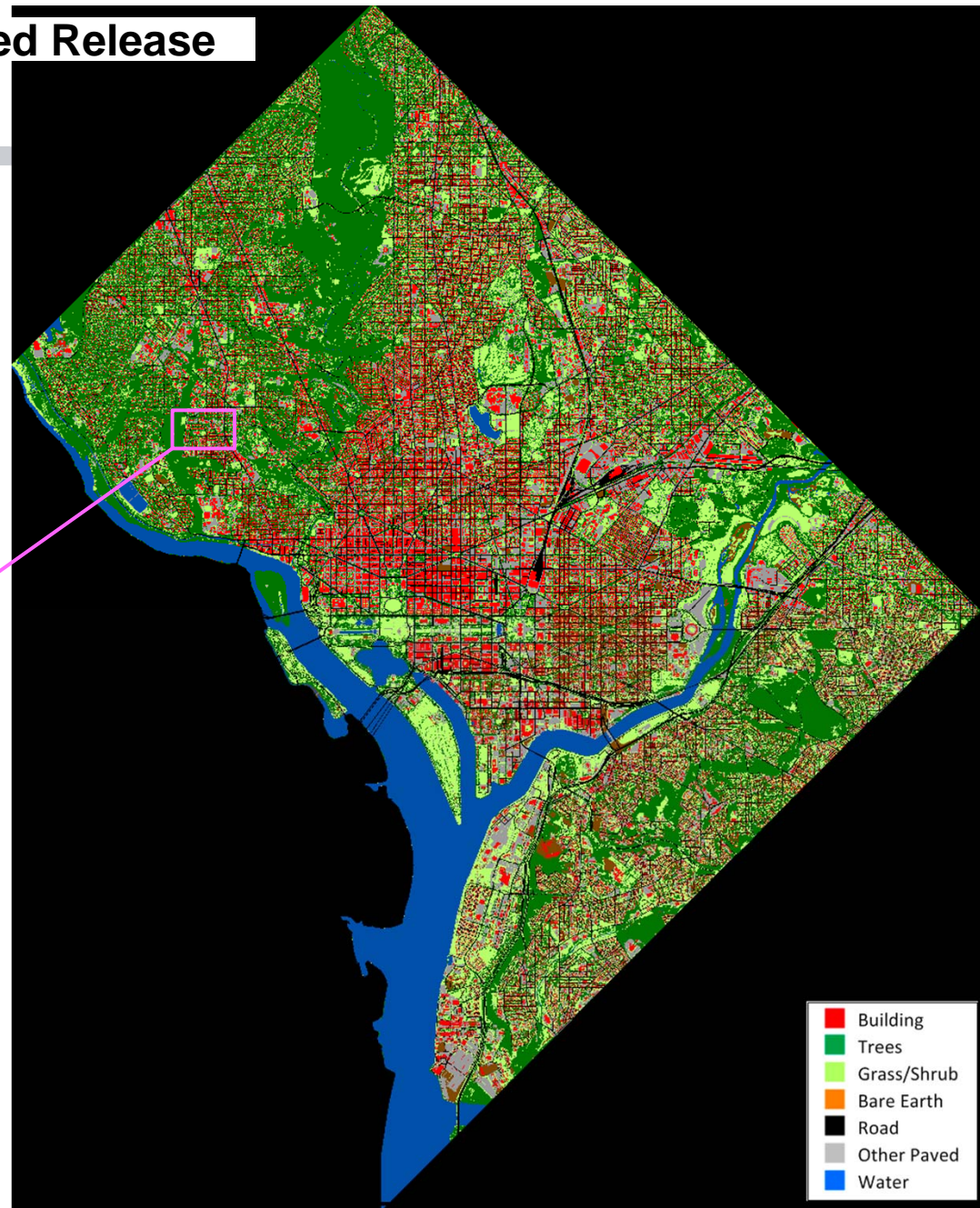
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Office of Defense Nuclear Nonproliferation R&D



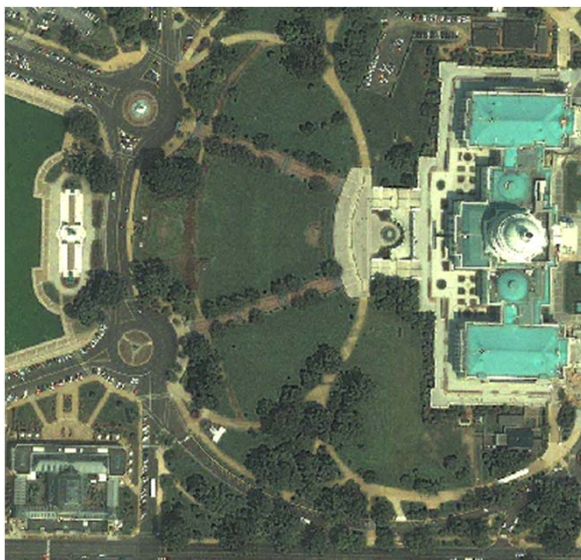
U.S. DEPARTMENT OF ENERGY
ENERGY Land Cover

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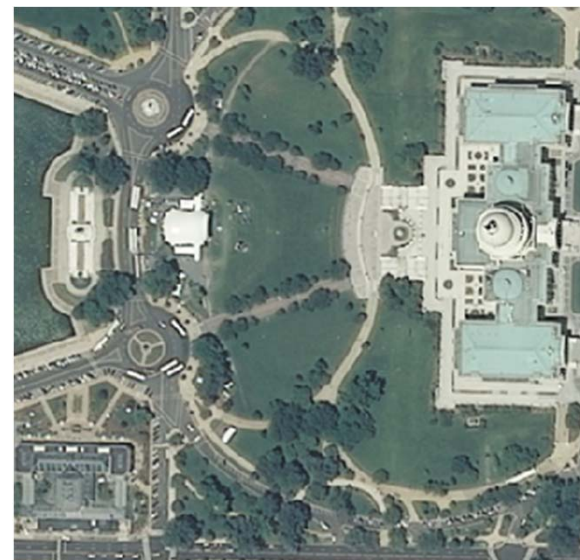


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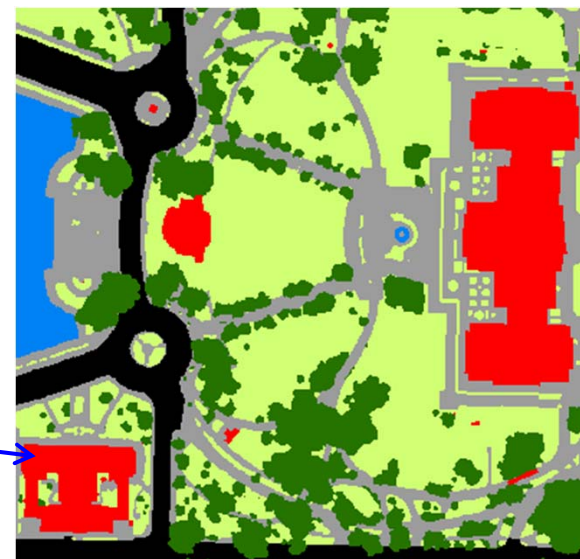
Comparing 2006 and 2011:



2006



2011



Difference in
precision causes
pseudo-change.

- **Motivation.**
- **Basic concepts.**
- **Results:**
 - Data.
 - – Geospatial search.
 - Geospatial-temporal search.
- **Summary.**

Unclassified Unlimited Release Power Plant Search

Query specification:

A power plant is a heat building with a transformer, and optional storage tank, evaporation pond, coal pile, body of water.

Question semantics:

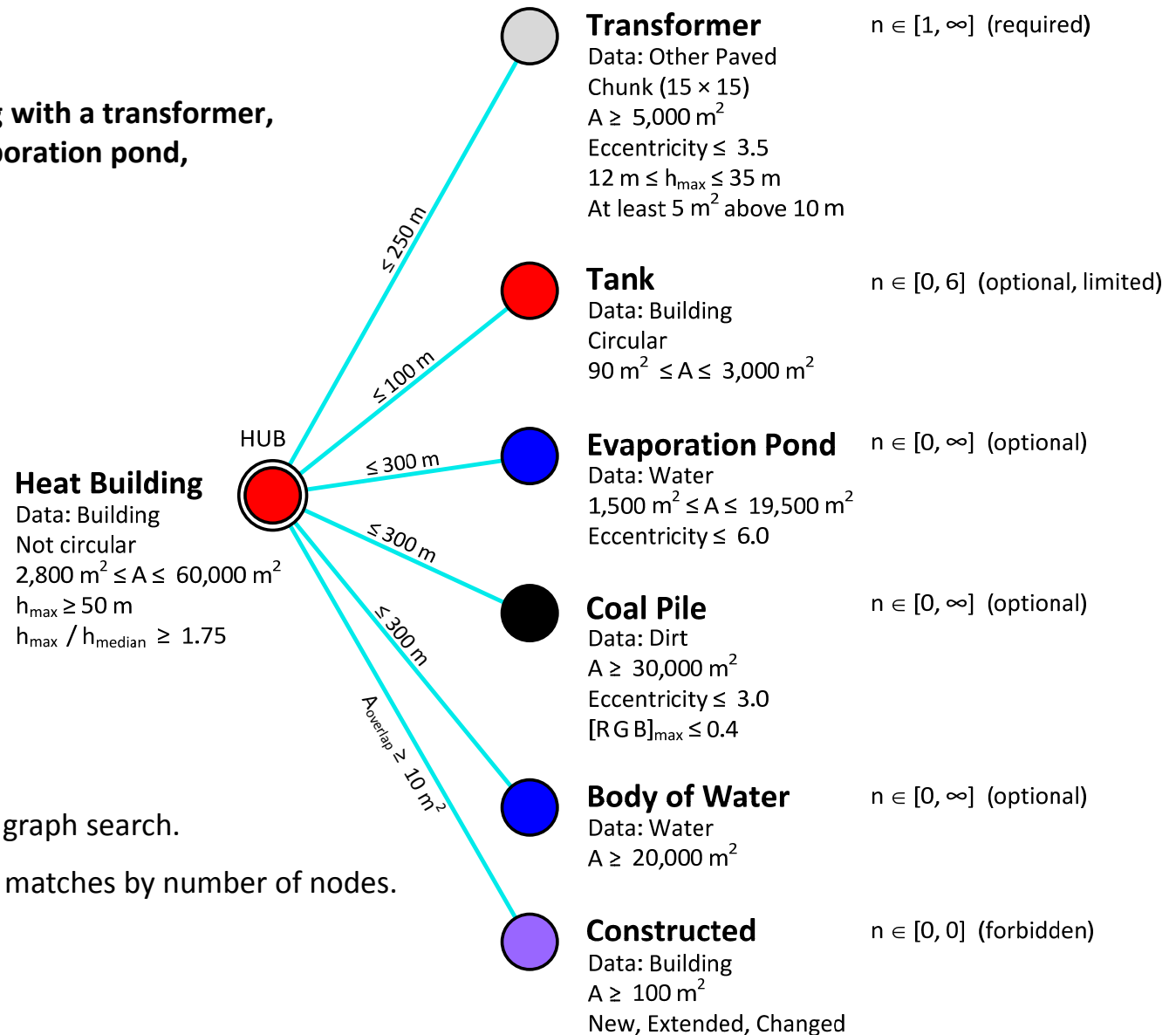
Heat Building
Transformer
Cooling Tower
Evaporation Pond
Body of Water
Coal Pile
Storage Tanks
Processing Tower
Pipe Network
⋮

Data semantics:

Building
Road
Other Paved
Grass/Shrub
Trees
Dirt
Water

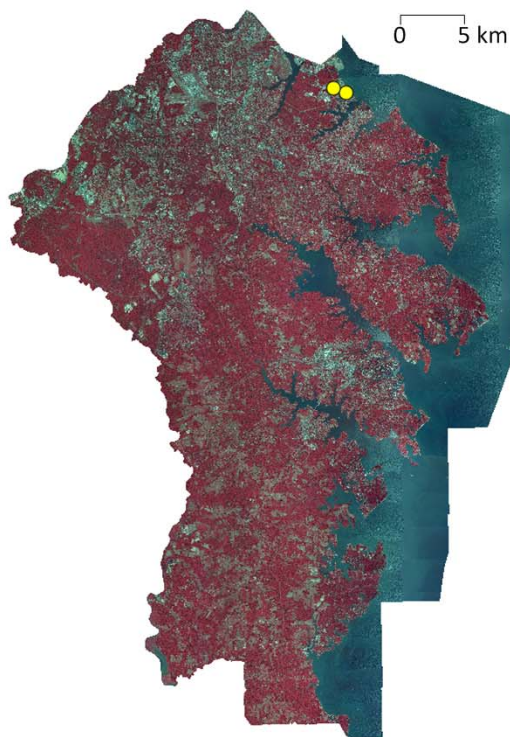
Star graph search.

Sort matches by number of nodes.

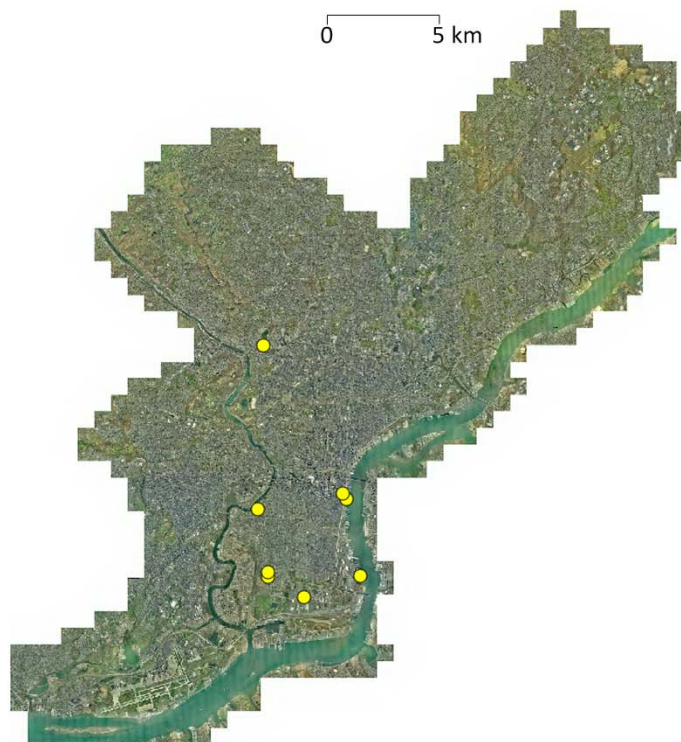


Unclassified Unlimited Release Power Plant Search

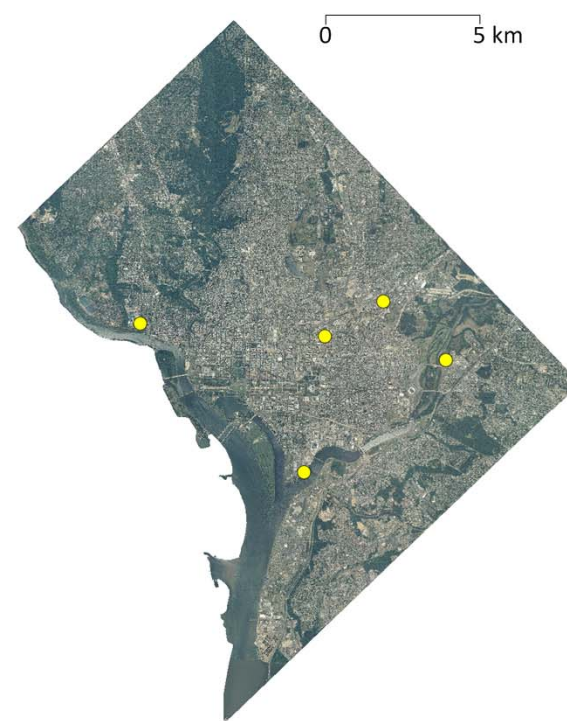
Search results:



Anne Arundel County, MD



Philadelphia, PA

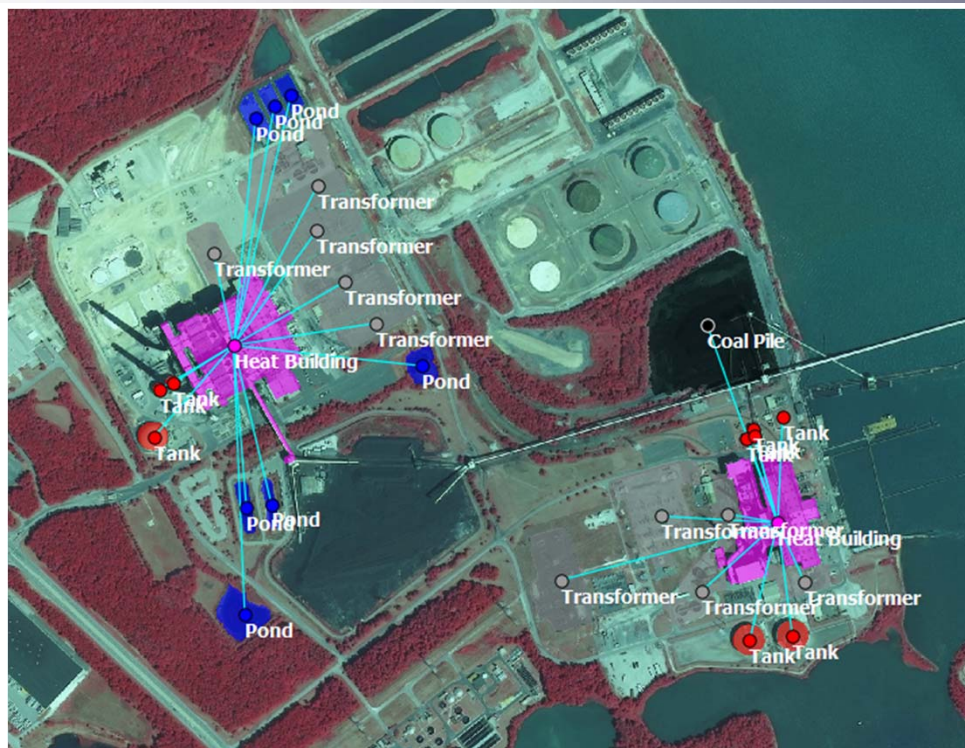


Washington, DC

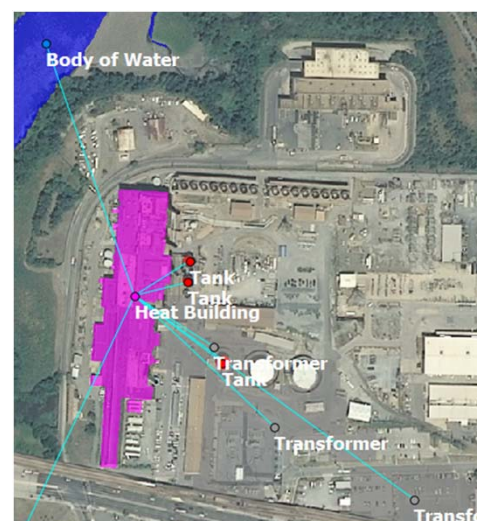
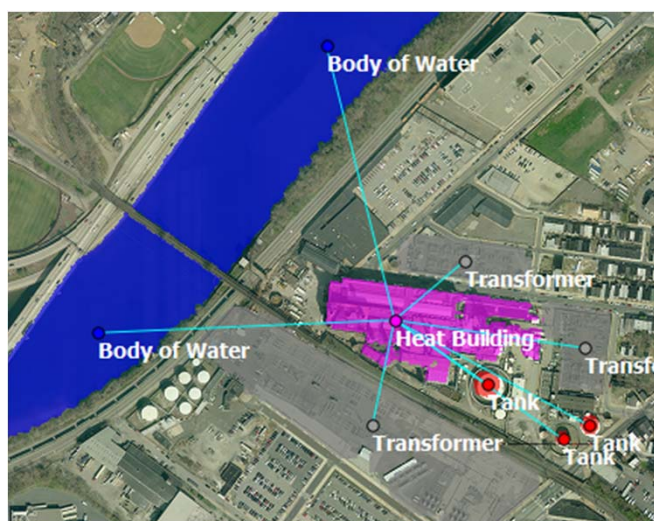
2,067 km² total area
135 billion Pixels
3.6 million Features

6 Power Plants
+ 9 False positives

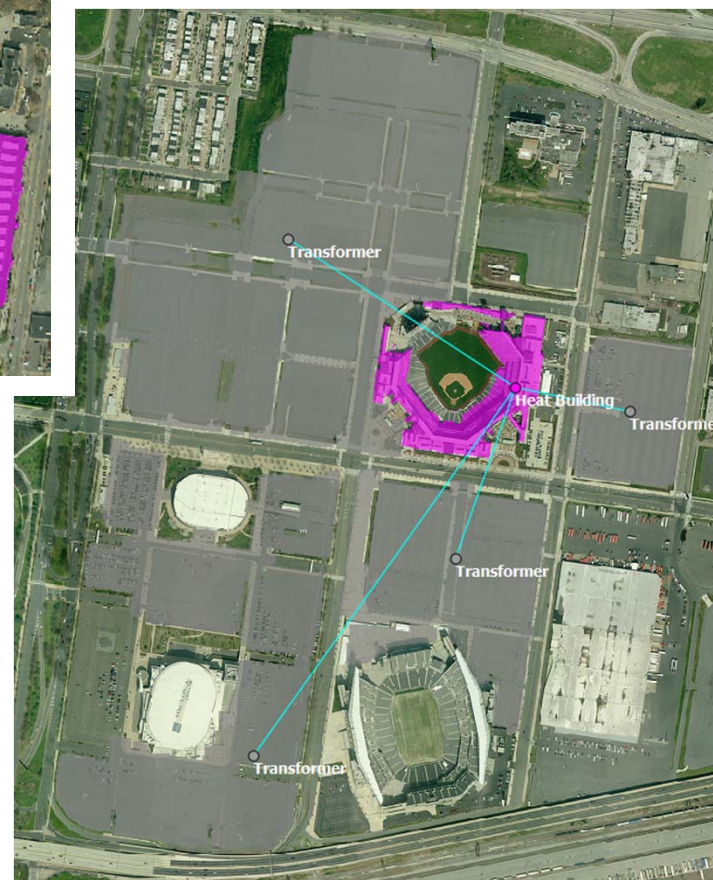
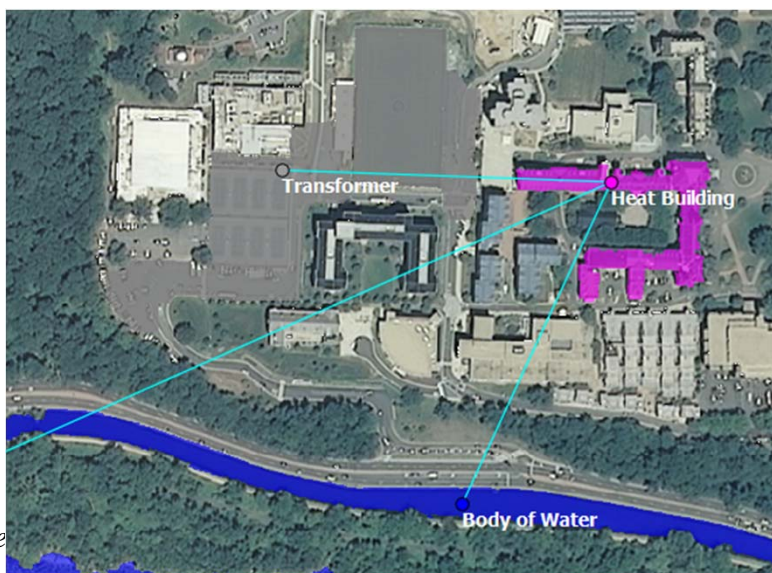
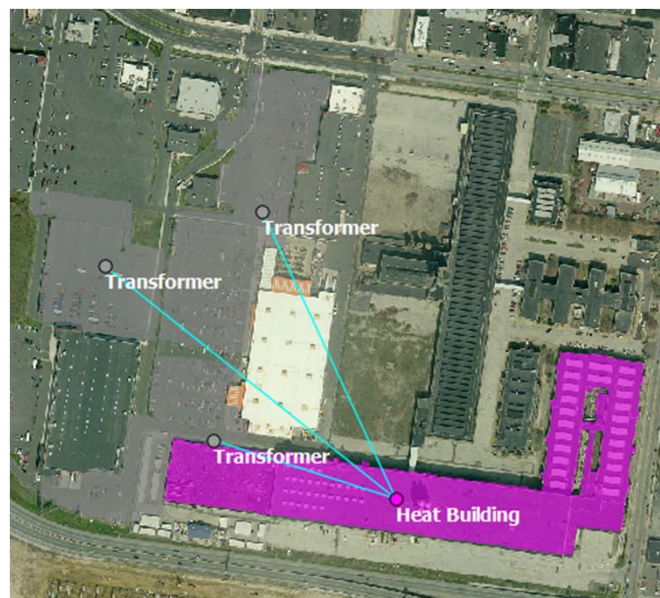
Unclassified Unlimited Release True Positives



Note that power plants were found despite several land cover classification errors.



Unclassified Unlimited Release False Positives



False negative evaluation forthcoming.

Unclassified Unlimited Release Refinery Search

Query specification:

Storage tank is a circular building.

Processing tower is a tall building with a small footprint.

Refinery is a complex tanks and processing towers.

A large refinery has at least 10 of each.

Question semantics:

Heat Building

Transformer

Cooling Tower

Evaporation Pond

Body of Water

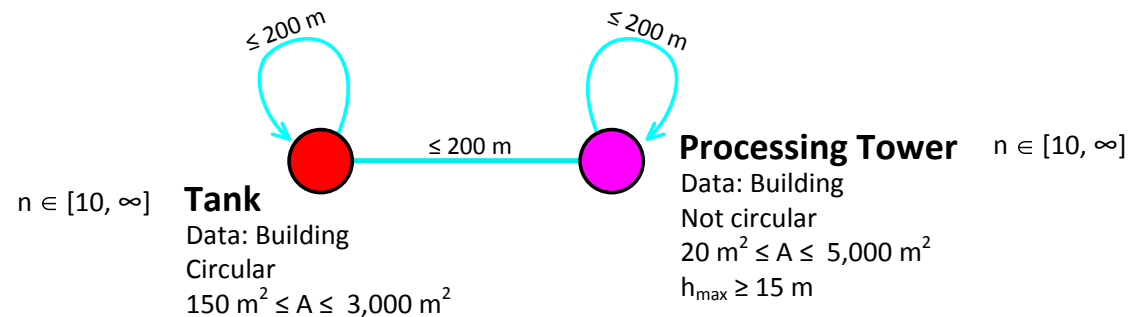
Coal Pile

Storage Tanks

Processing Tower

Pipe Network

⋮



Data semantics:

Building

Road

Other Paved

Grass/Shrub

Trees

Dirt

Water

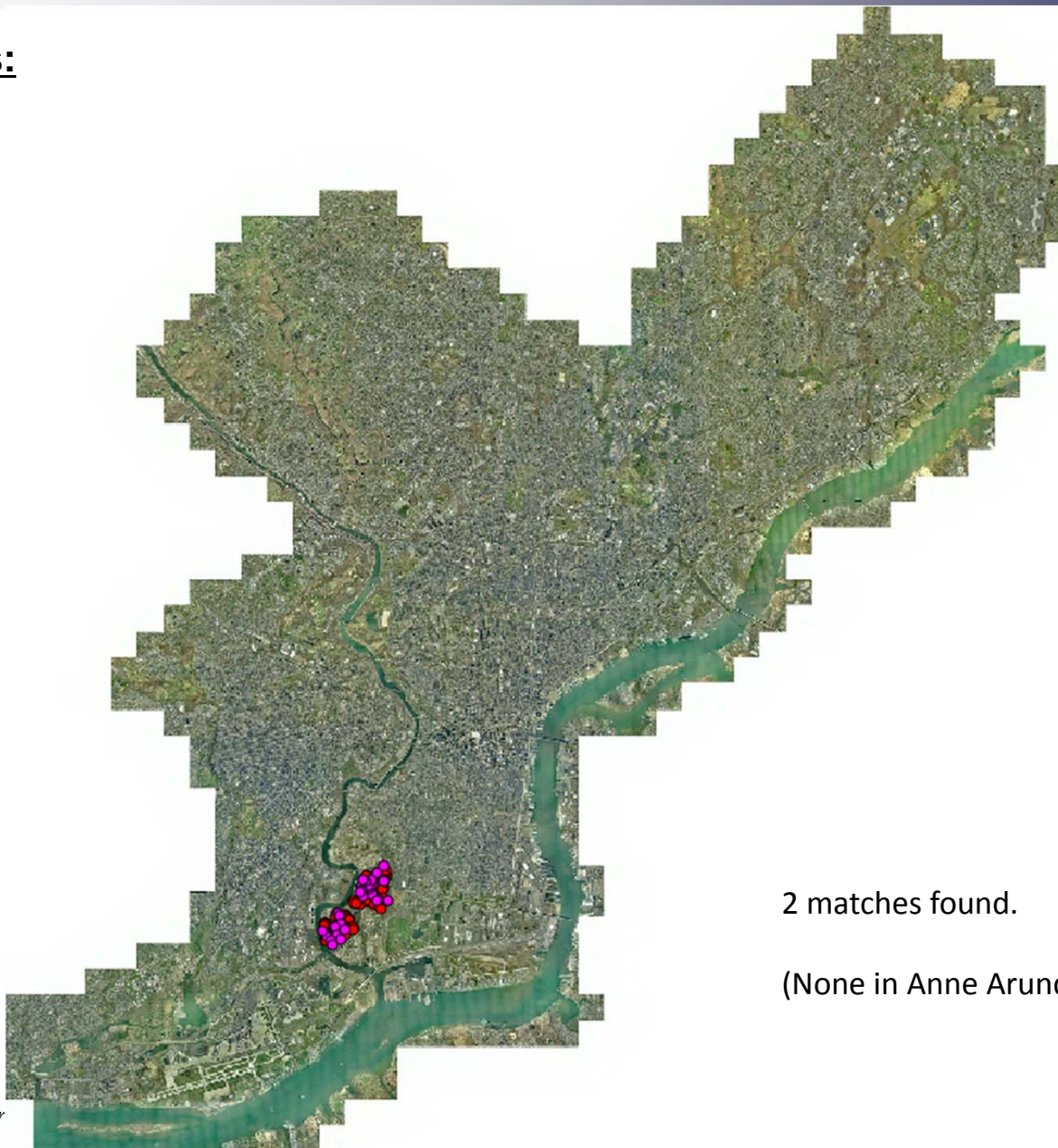
Heterogeneous complex search.

Sort matches by number of nodes.

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Unclassified Unlimited Release Large Refinery Search

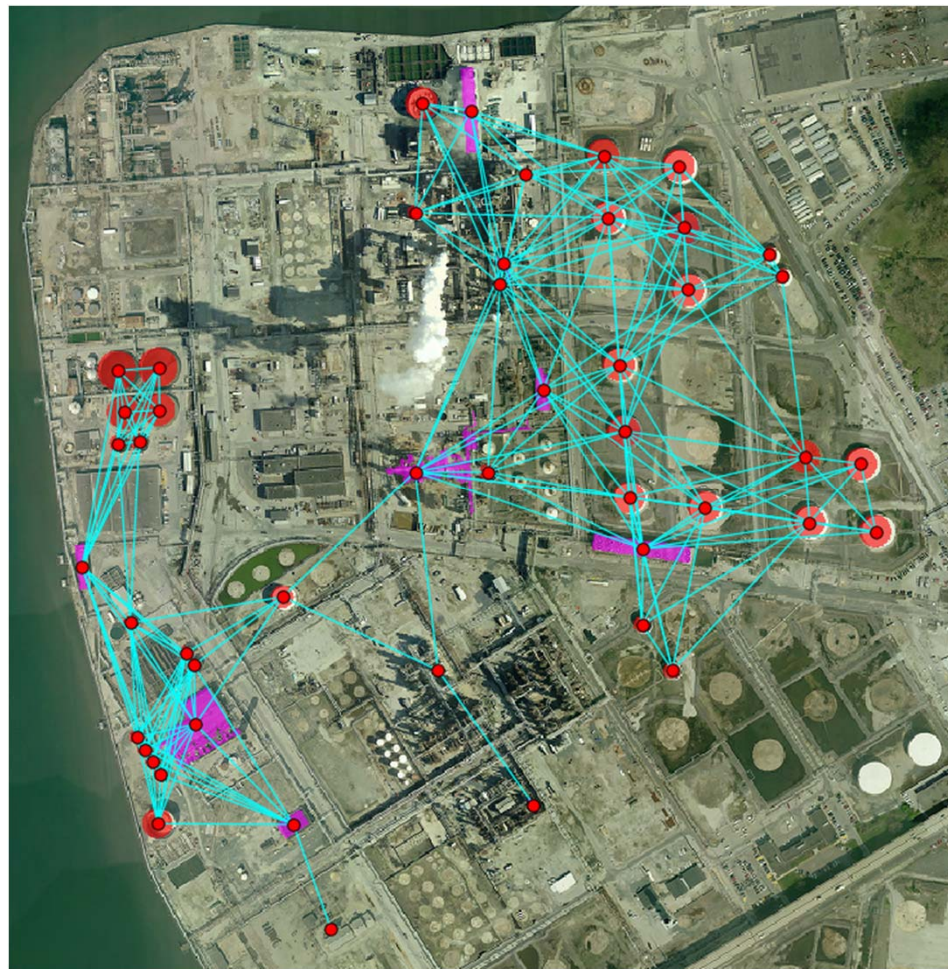
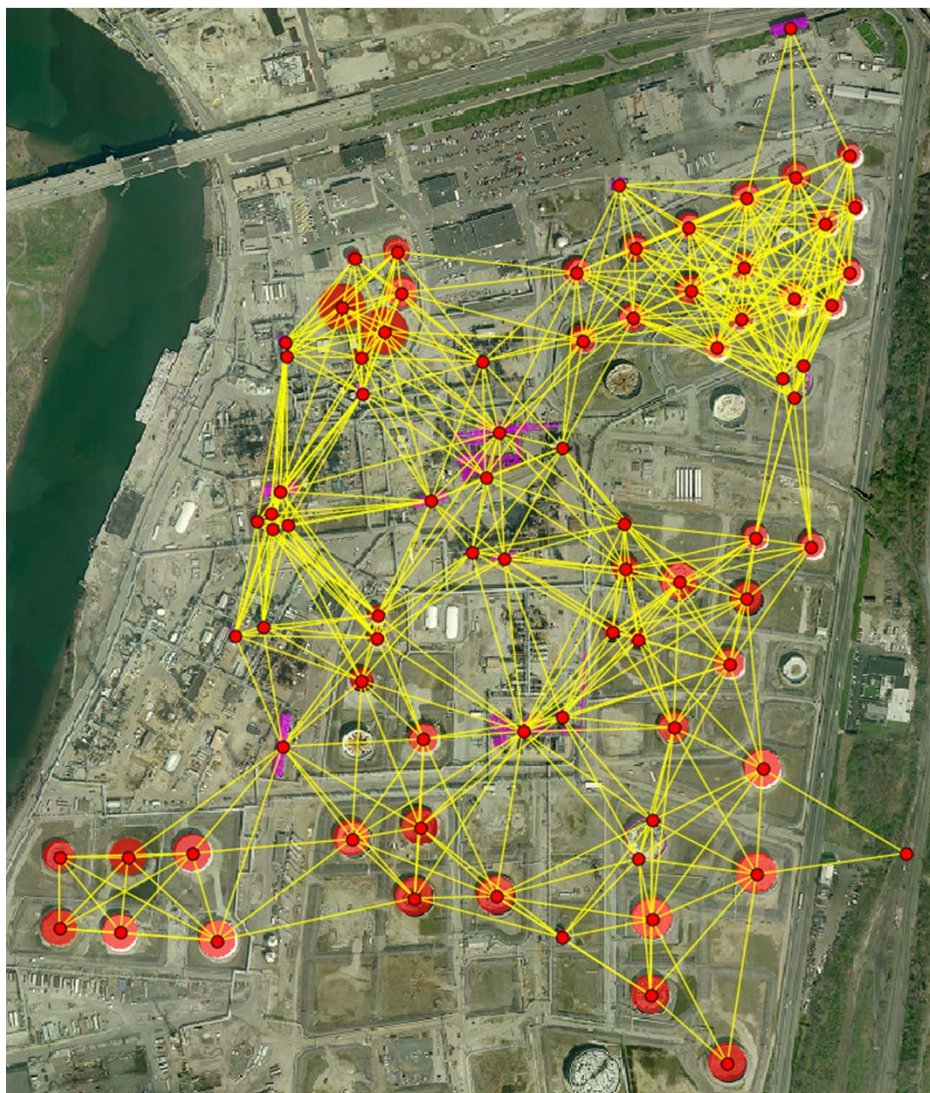
Search results:



2 matches found.

(None in Anne Arundel or Washington.)

Refineries found:



Office of Defense Nuclear Nonproliferation R&D

Distilling the search for large refineries (Philadelphia only):

Raw data points/pixels	101,495,378,523
Landcover pixels	8,981,933,044
Regions	1,133,822
Graph nodes	1,133,822
Buildings	154,062
Medium size buildings	87,170
Tank candidates	371
Tank complexes	28
Large refineries	2

This search effectively reduced the information content
to a small number of focus areas for user attention.

- **Motivation.**
- **Basic concepts.**
- **Results:**
 - Data.
 - Geospatial search.
 - – Geospatial-temporal search.
- **Summary.**

Unclassified Unlimited Release Simple Change Example

Context:



Land cover for two time slices:



2006

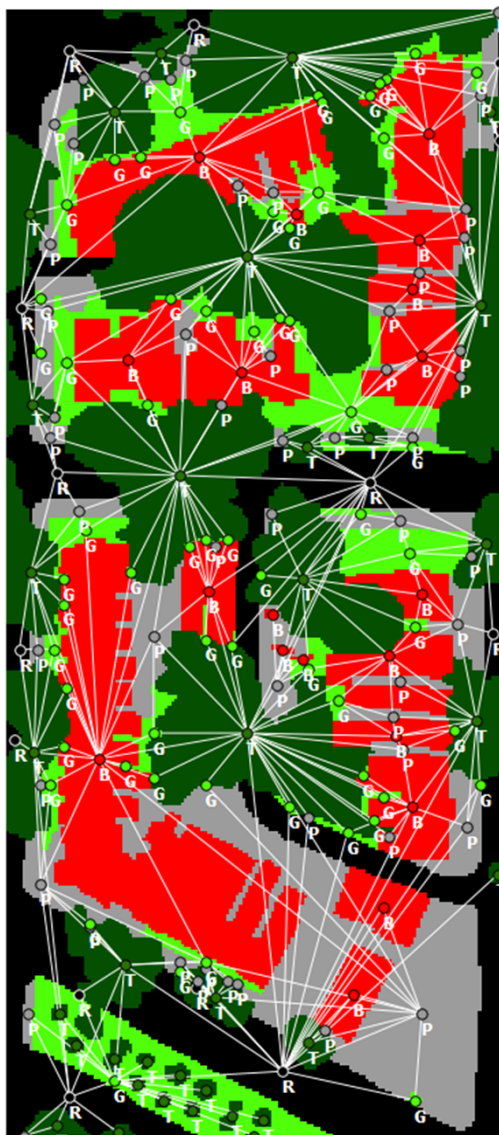


2011

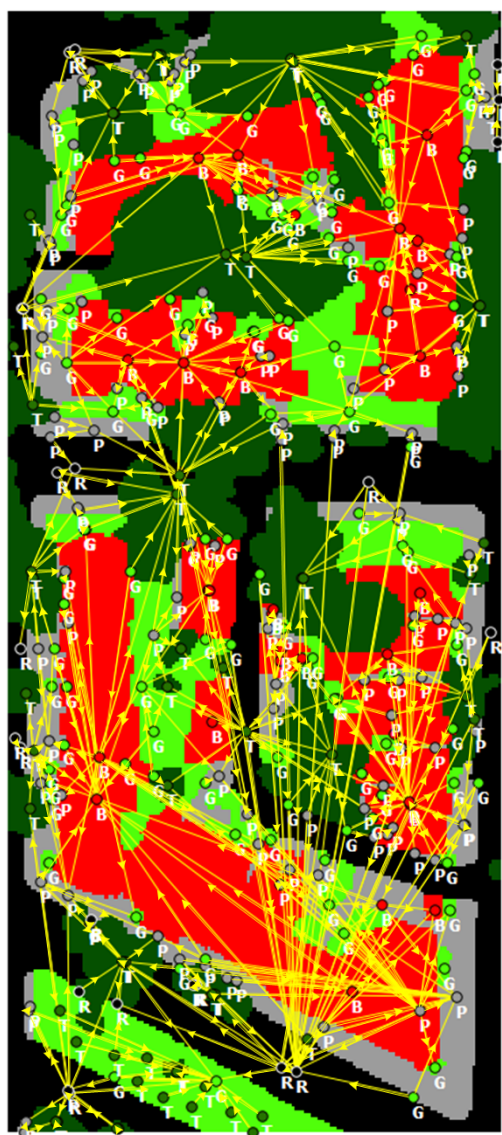
Unclassified Unlimited Release Graph-Based Analysis

342 nodes
808 adjacency edges
559 change edges
0 distance edges

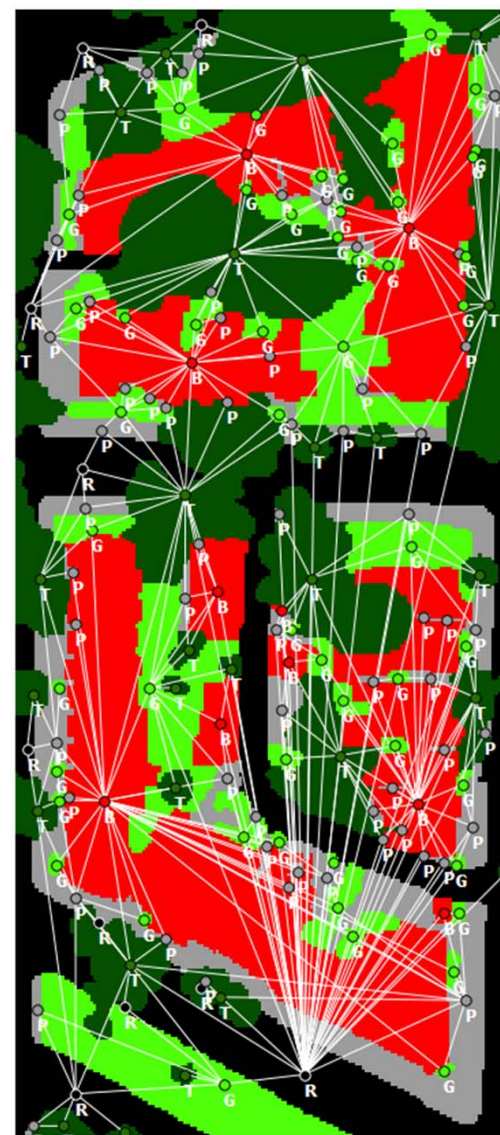
Geospatial-temporal graph:



2006 Adjacency



2006 → 2011 Change



2011 Adjacency



Unclassified Unlimited Release Differentiating Important Change

Significant change diagnosis:

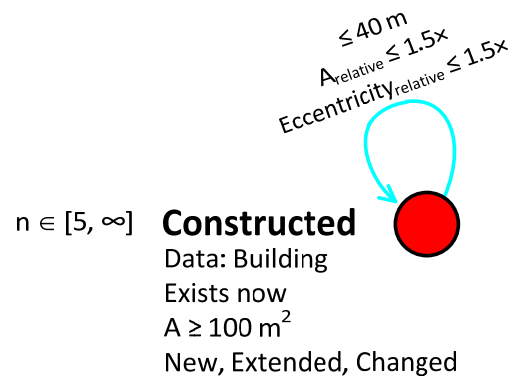


Query specification:

Where are complexes of new similar buildings?

Question semantics:

Building
Changed Building
Extended Building
Merged Building
New Building
Replaced Building
Constructed
⋮



Data semantics:

Building
Road
Other Paved
Grass/Shrub
Trees
Dirt
Water

Connected component search.

Sort matches by number of nodes.



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Unclassified Unlimited Release New Complexes

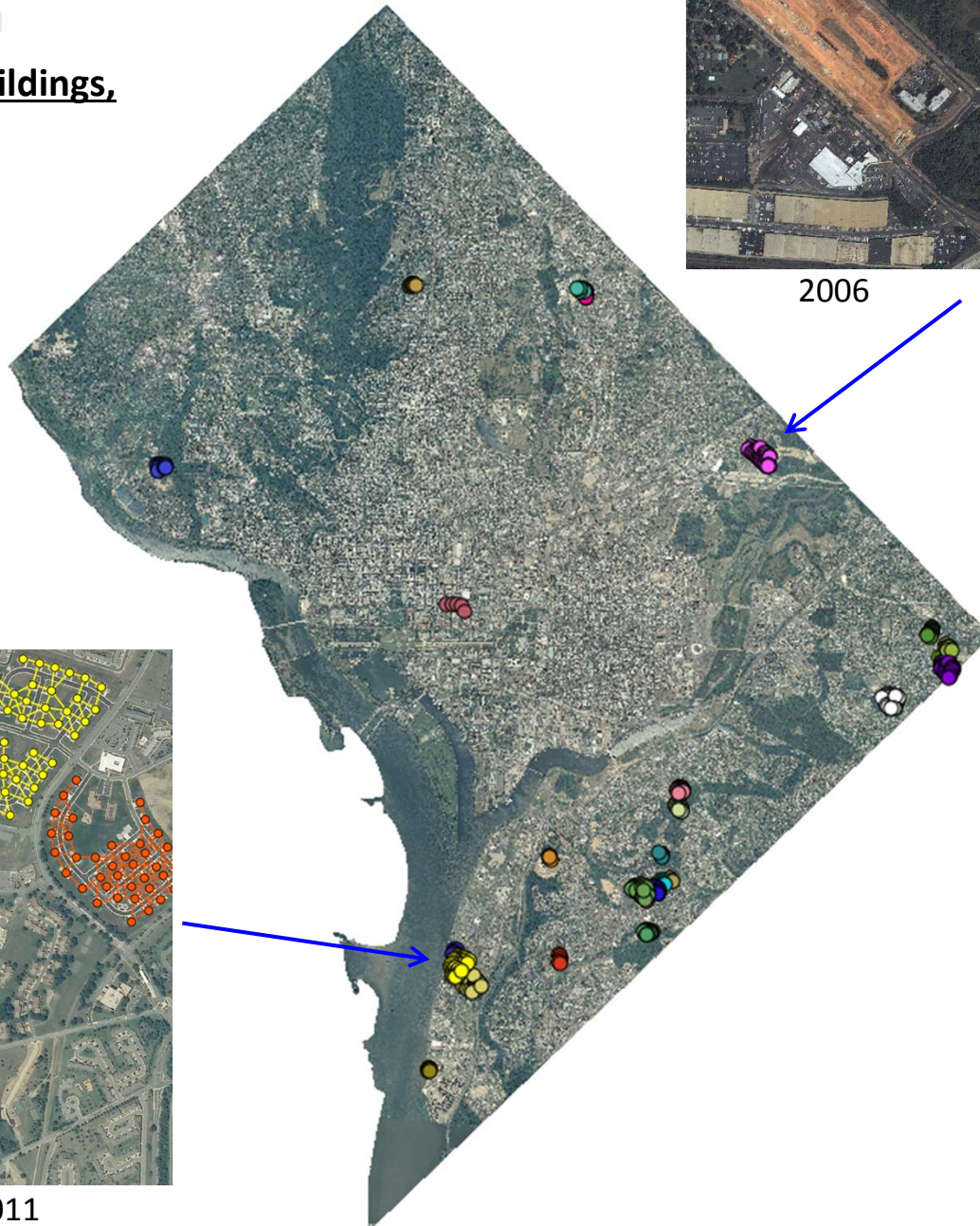
Seek complexes of new buildings,
across the entire city:



2006



2011

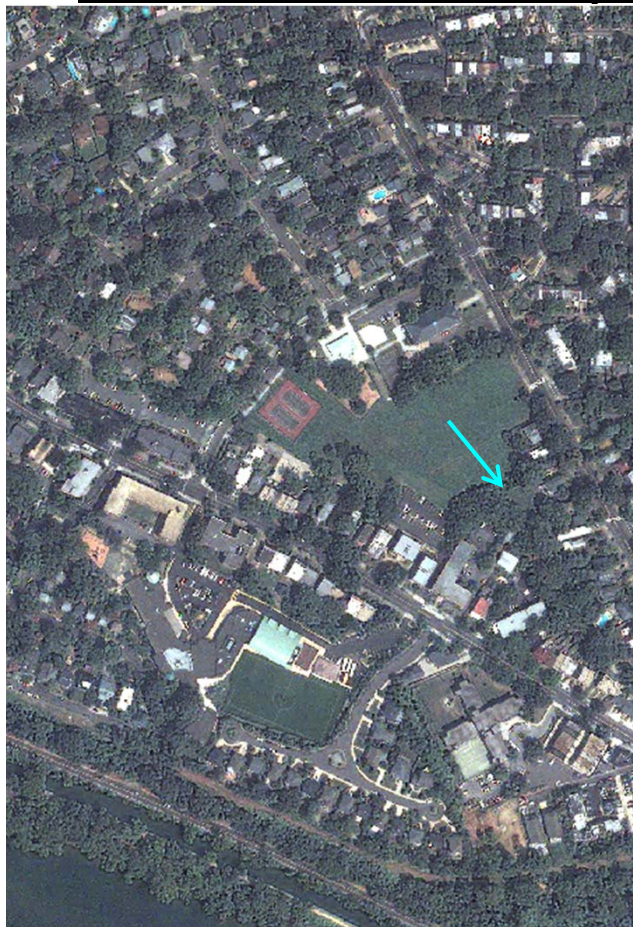


2006

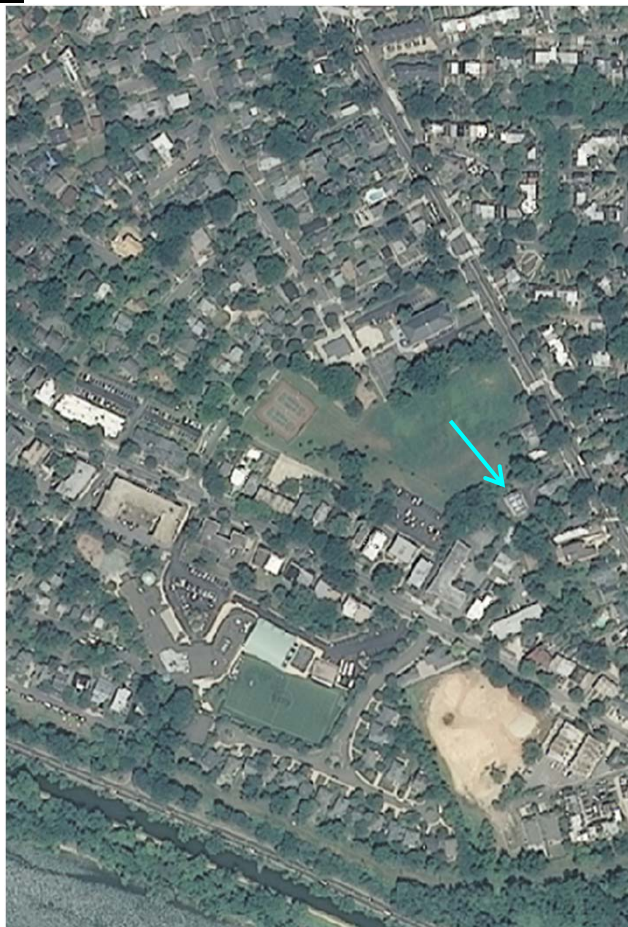


2011

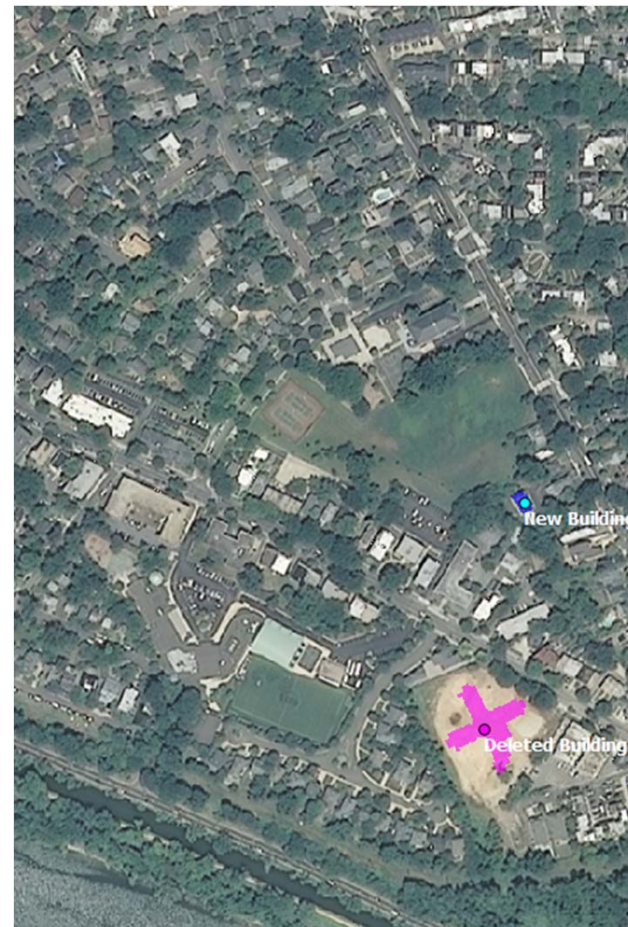
An area in the northwest part



2006



2011



New and Deleted Buildings

Imagine trying to find this by visually scanning the entire city!

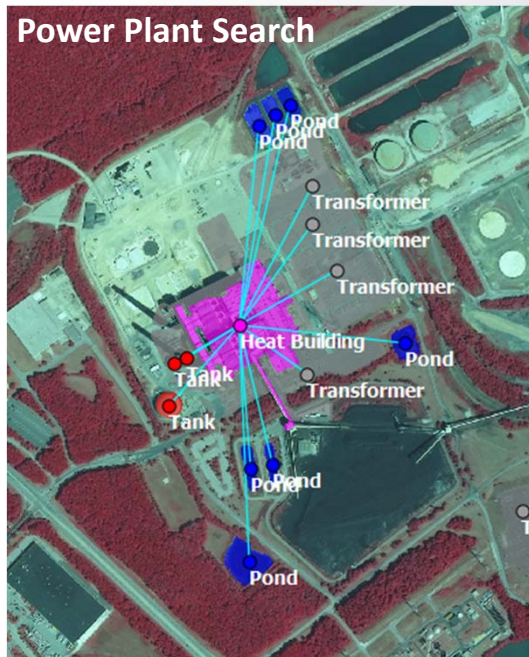
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- Motivation.
- Basic concepts.
- Technical details.
- Results.
- • Summary.



Unclassified Unlimited Release Diversity of Problems

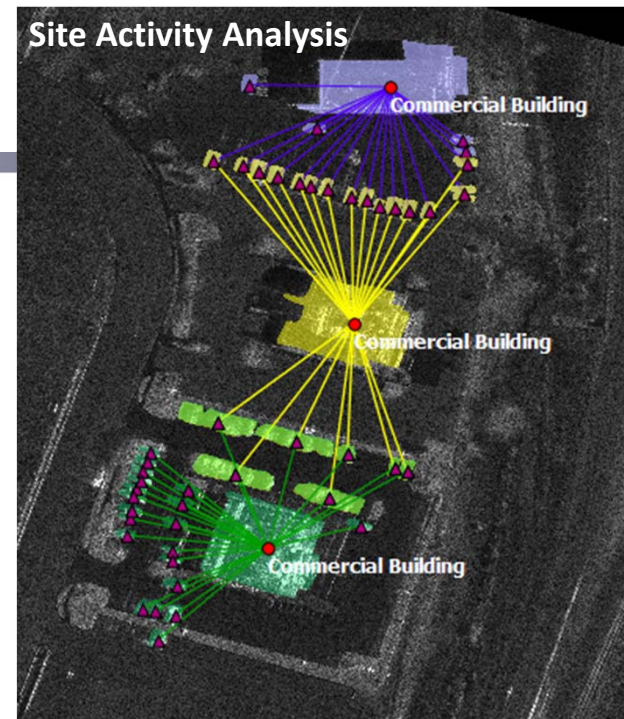
Power Plant Search



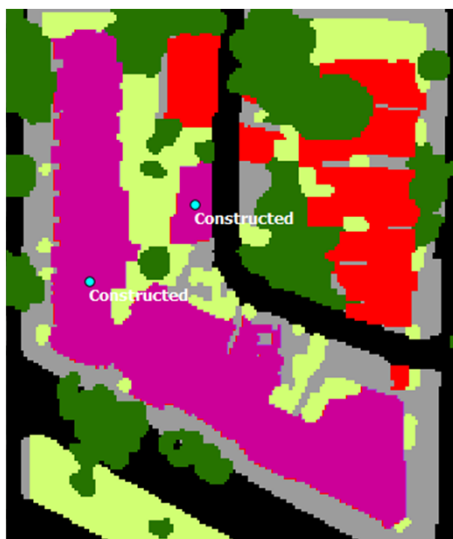
Tank Complex Search



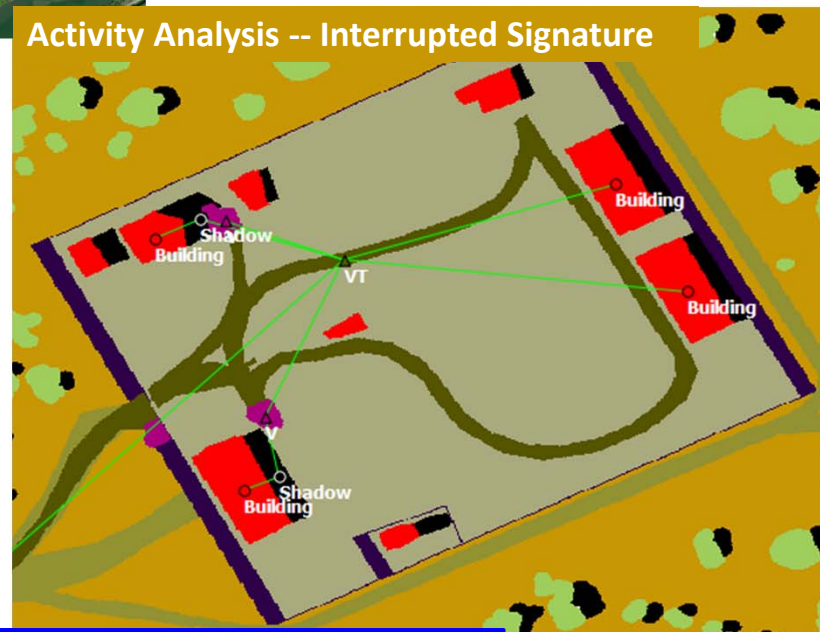
Site Activity Analysis



Construction Analysis



Activity Analysis -- Interrupted Signature



Challenges:

- **This is not perfect!**
- **Still working to understand scope, relation to other methods.**
- **Not finished testing.**
- **Quality scoring/uncertainty characterization.**
- **Easy query design.**
- **Image pre-processing risk.**
- **Domain-specific issues.**

BACKUP SLIDES

Large graphs constructed so far:

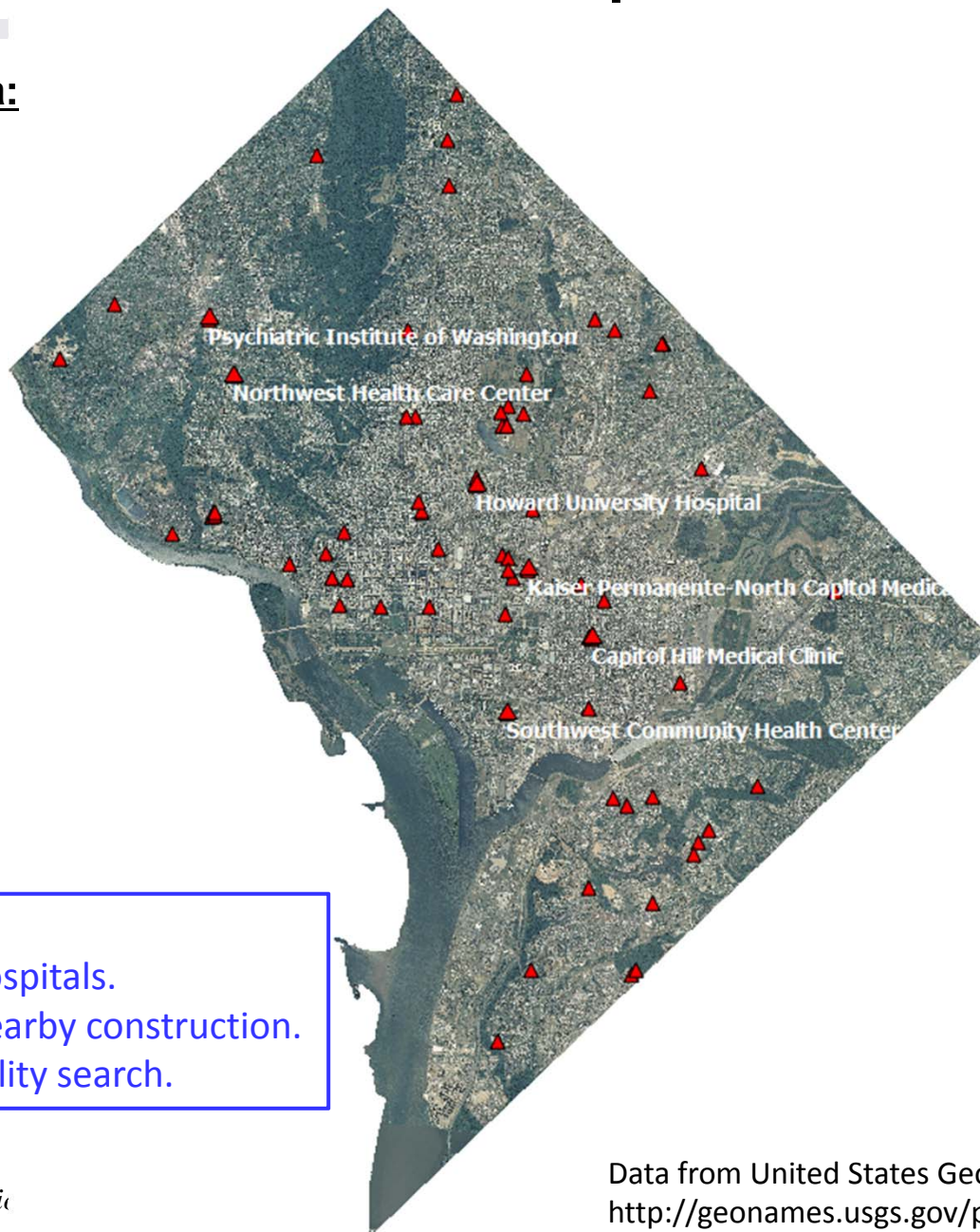
	<u>Landcover Pixels*</u>	<u>Nodes</u>	<u>Graph File</u>
■ Single-time:			
■ Anne Arundel County.	4.1 GPix	1,204,087	1.6 GB
■ Greater Baltimore (sliced).	11.3 GPix	3,488,712	4.5 GB
■ Two-time:			
■ Washington, DC.	1.0 GPix	1,326,212	1.7 GB
■ Philadelphia.	3.8 GPix	1,540,909	2.0 GB

* Only includes land-area pixels,
not blank filler space.



Unclassified Unlimited Release Construction Near Hospitals

Hospitals in the DC area:



Goals:

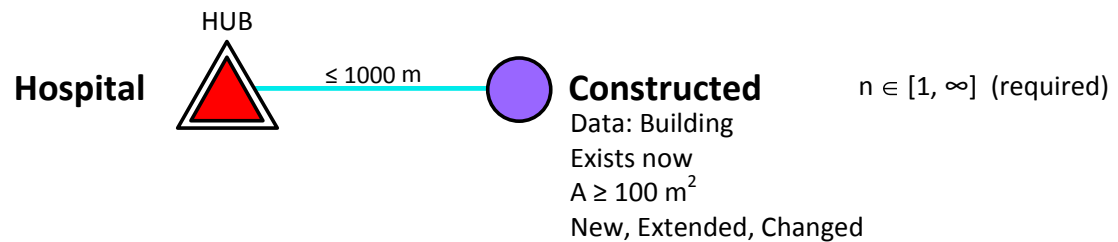
1. Find construction near hospitals.
2. Estimate magnitude of nearby construction.
3. Demonstrate multi-modality search.

Query specification:

How much construction has occurred within 1 km of each hospital?

Question semantics:

Building
Changed Building
Extended Building
Merged Building
New Building
Replaced Building
Constructed
Hospital
⋮



Data semantics:

Building
Road
Other Paved
Grass/Shrub
Trees
Dirt
Water
Hospital

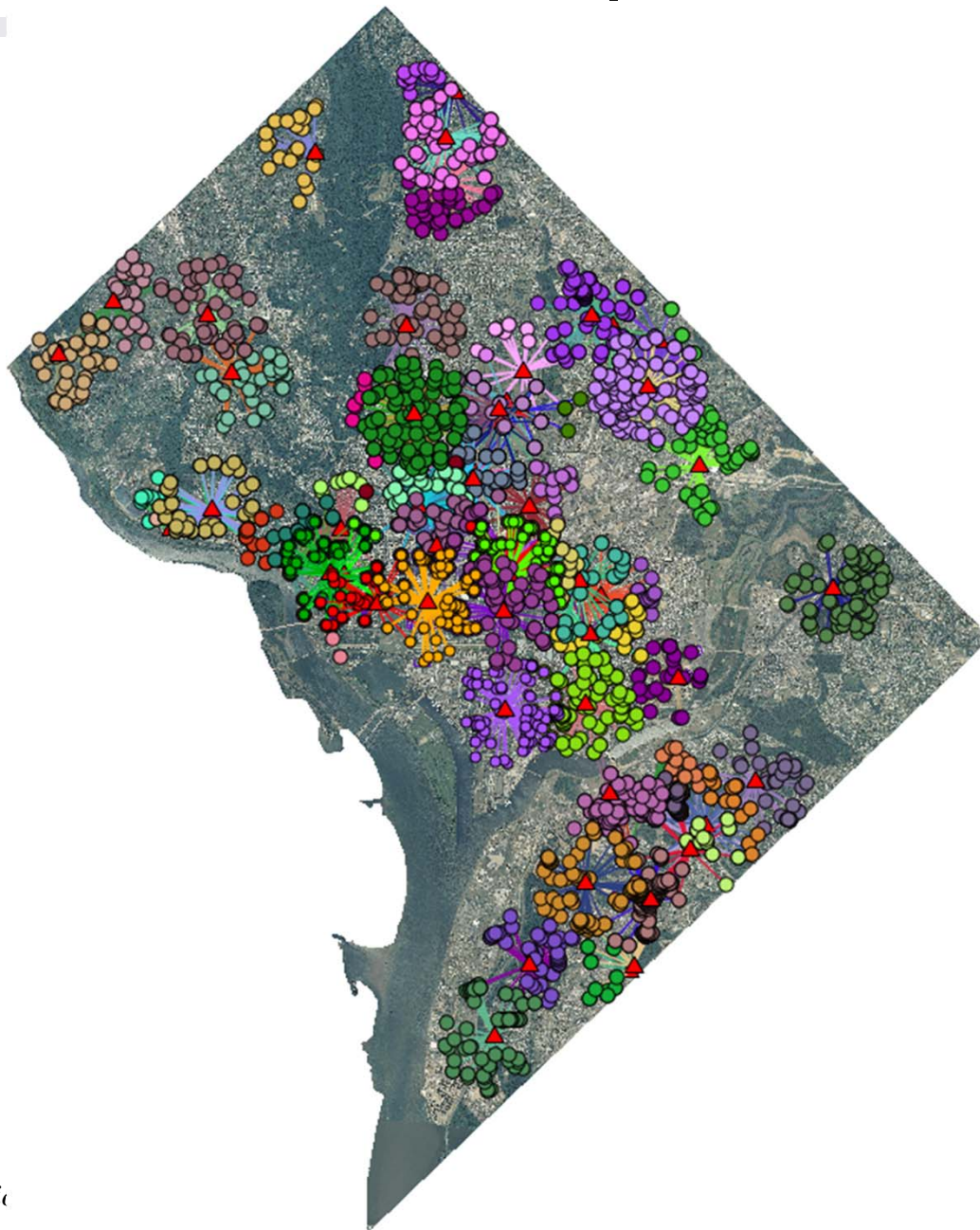
Star graph search.

Rank in order of most construction first.

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Unclassified Unlimited Release Construction Near Hospitals

All matches:



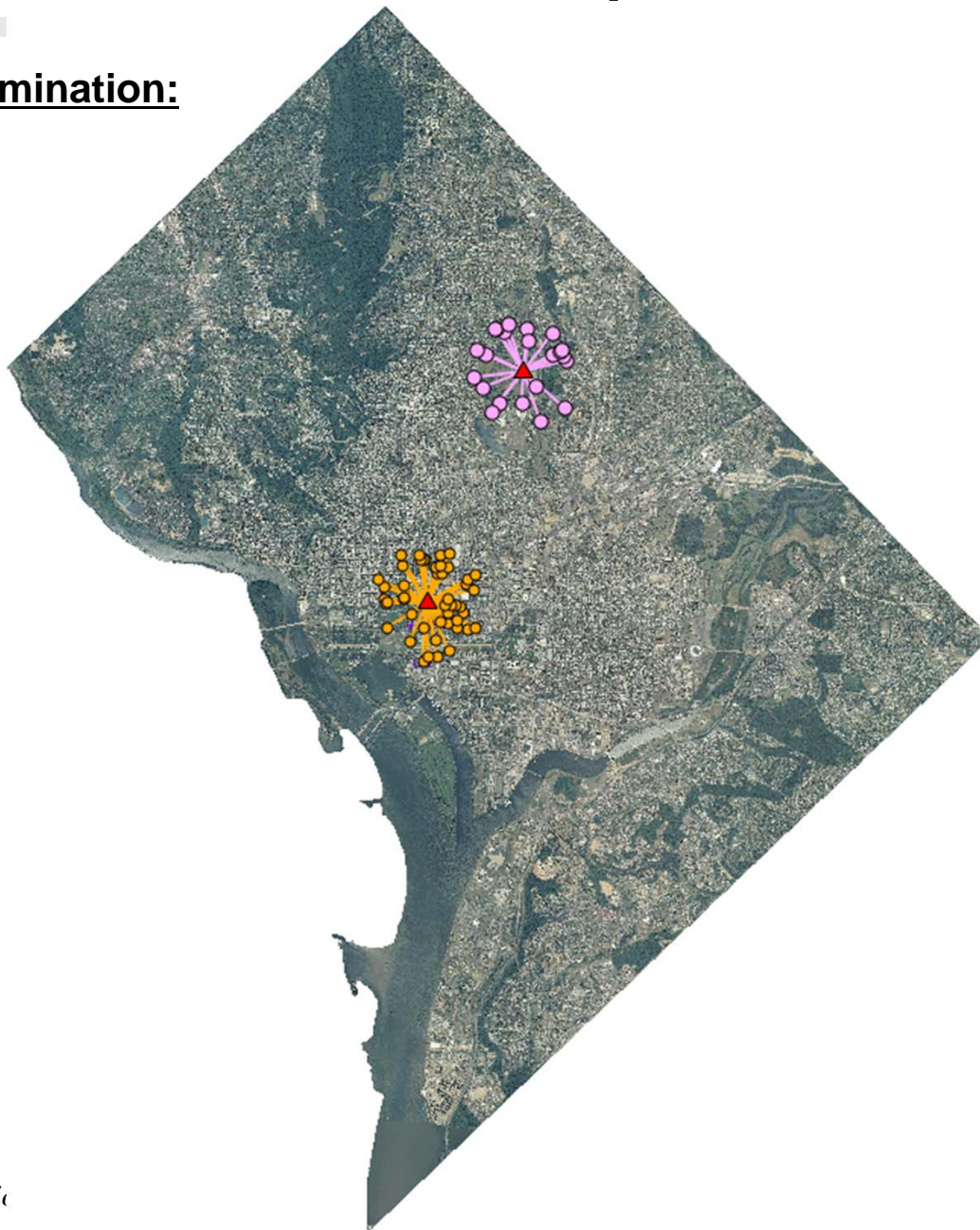


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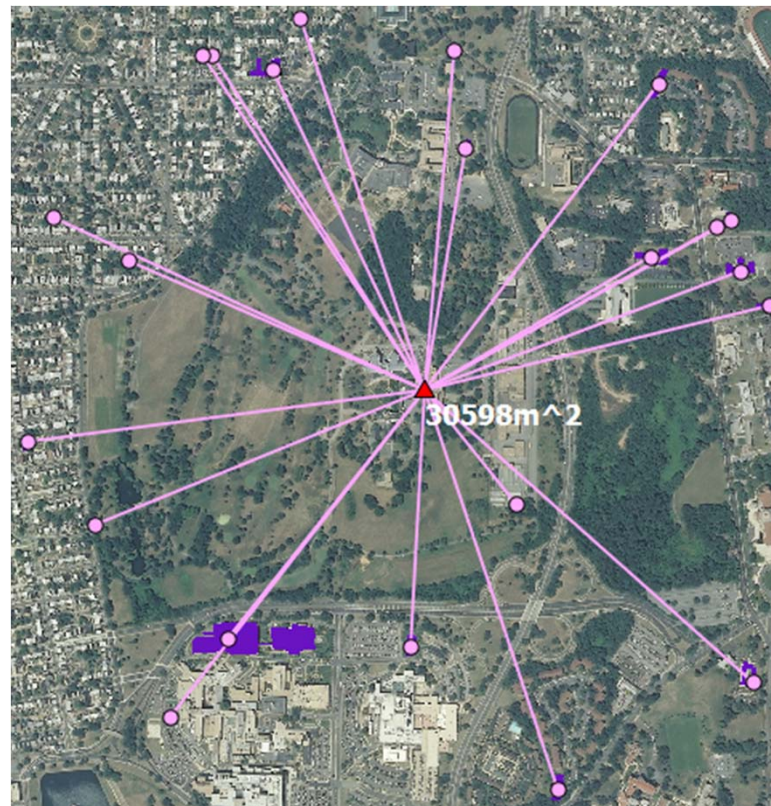
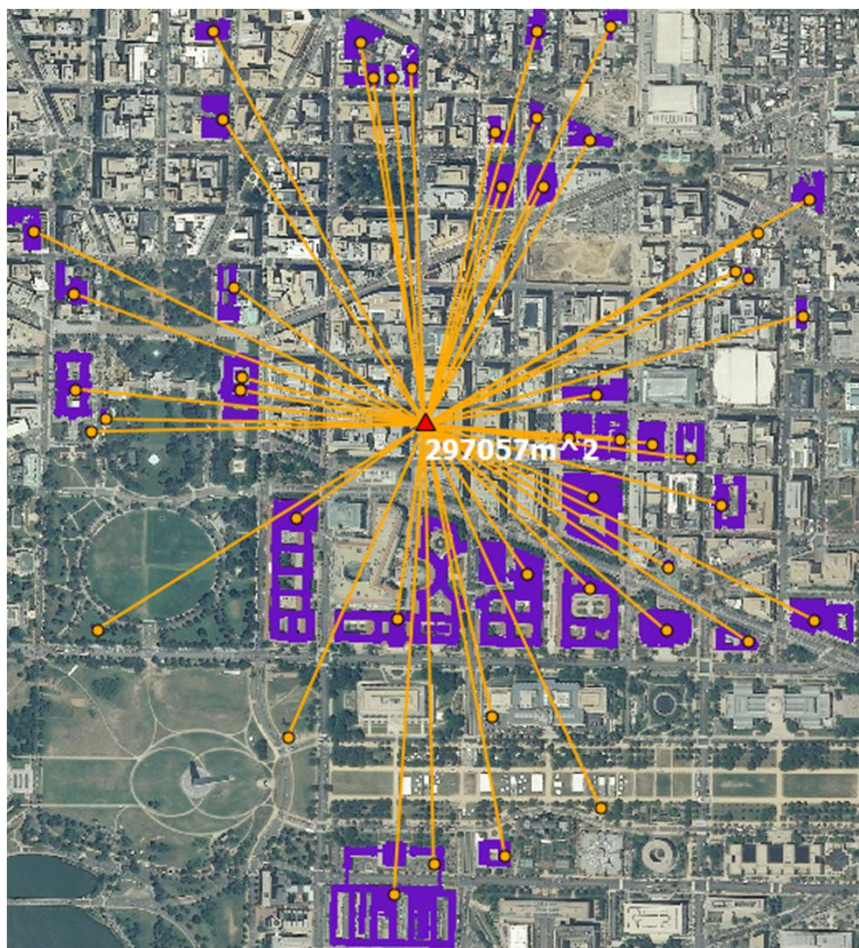
Unclassified Unlimited Release Construction Near Hospitals



Select two for close examination:



Hospital with different amounts of nearby construction:*



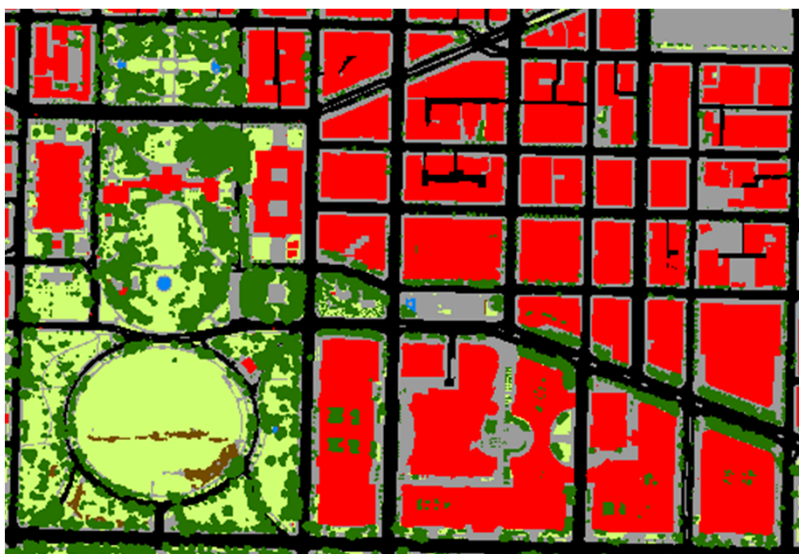
One computation includes:

- Temporal change detection.
- Construction diagnosis.
- Image and text data.
- Post-processing numerical sum.

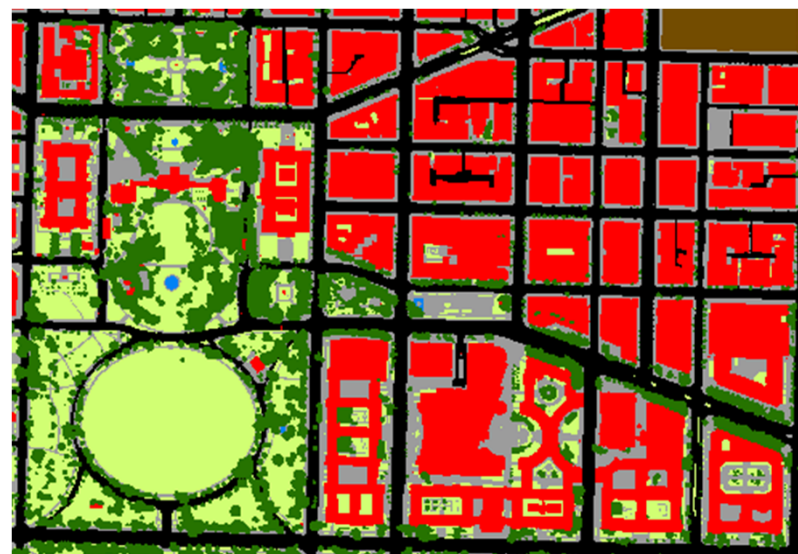
* Includes pseudo-construction. See above.



Pseudo-change due to different data precision:



2006



2011

Given these data, our change analysis code is producing correct results.

This emphasizes the importance of ensuring compatibility between observations when making comparisons.

Our Philadelphia data set is expected to have higher consistency across time.

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