Ontology-Based Software for Generating Scenarios for Characterizing Searches for Nuclear Materials

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Project: SAM Ontology Demonstration for Scenario Generation for SNM Detection

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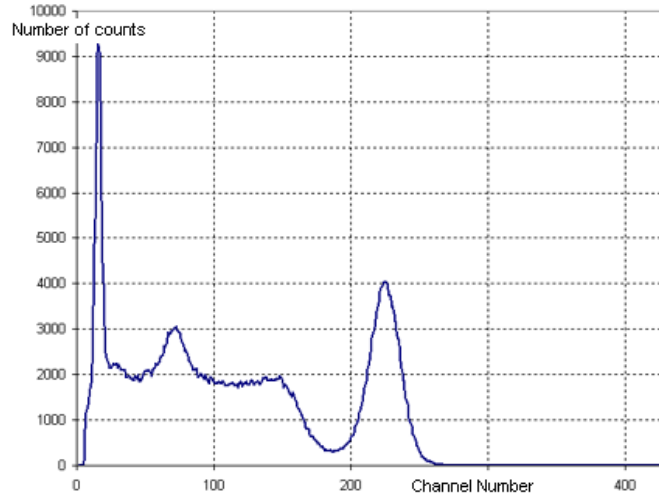
Threat posed by special nuclear materials

- SNM defined as: plutonium, uranium-233, or uranium enriched in the isotopes uranium-233 or uranium-235
- Poses acute national security threat in hands of terrorists or rogue nations
- Deterrence is critical; requires various means to detect SNM
  - Portal monitors
  - Vehicle mounted monitors
  - Pedestrian searchers with detectors

http://www.berkeleynucleonics.com/products/model_940.html

- To detect SNM one must resolve photon signature of characteristic gamma rays emitted by isotopes present
- Algorithms are used to separate SNM from background

Challenge for SNM Detection: Extract SNM signatures from radiation clutter

Detected Signal = 

+ Signal from Background Sources

Background Includes:

- Naturally Occurring Radioactive Material (NORM)
  - Composition of the soil near detector
- Benign sources that may enter and/or leave the detection area as part of everyday activities
  - Anthropogenic sources (medical isotopes, commercial sources)
- Building materials that may have a signature (ex, granite)
- Possible presence of technically-enhanced NORM (ex, fertilizers)
- Weather (rain, humidity)

What do we mean by a scenario?

Detection of **SNM material** by searcher using **NaI detector** carried in a **backpack**.

Movements of **searcher** and **other objects** (pedestrians, vehicles, etc.) in an **urban setting**

Information about an **SNM source**

Collection of **static and dynamic factors** that can mask the detection of the SNM source (NORM, anthropogenic sources, weather conditions, etc.)

Scenarios will be used for testing ability of algorithms to separate SNM from background given radiation clutter. Algorithms require scenarios for validation.

Typical approaches to scenario generation

- Automated scenario generation used in many areas
  - Training/planning, resource allocation, estimating risks, evaluating physical models, etc.
- These scenario generation approaches typically
  - Use a fixed set of variables
  - Depend on frequent subject matter expert oversight
  - Incur high cost for adding alternative sets of scenarios

Automated scenario generation for flight training:

Scenario generators developed for closed, pre-determined domains

Reference: Martin and Hughes (2010) "A Scenario Generation Framework for Automating Instructional Support for Scenario-based Training"

Automated generation of crisis management training scenarios:

Selection bias (using ScenGen) "significantly limits its accessibility to many portions of the search space"

Reference: Grois, Hus, Voloshin, and Wilkins (1998) "Network Model for Generation of Crisis Management Training Scenarios"

Project goals

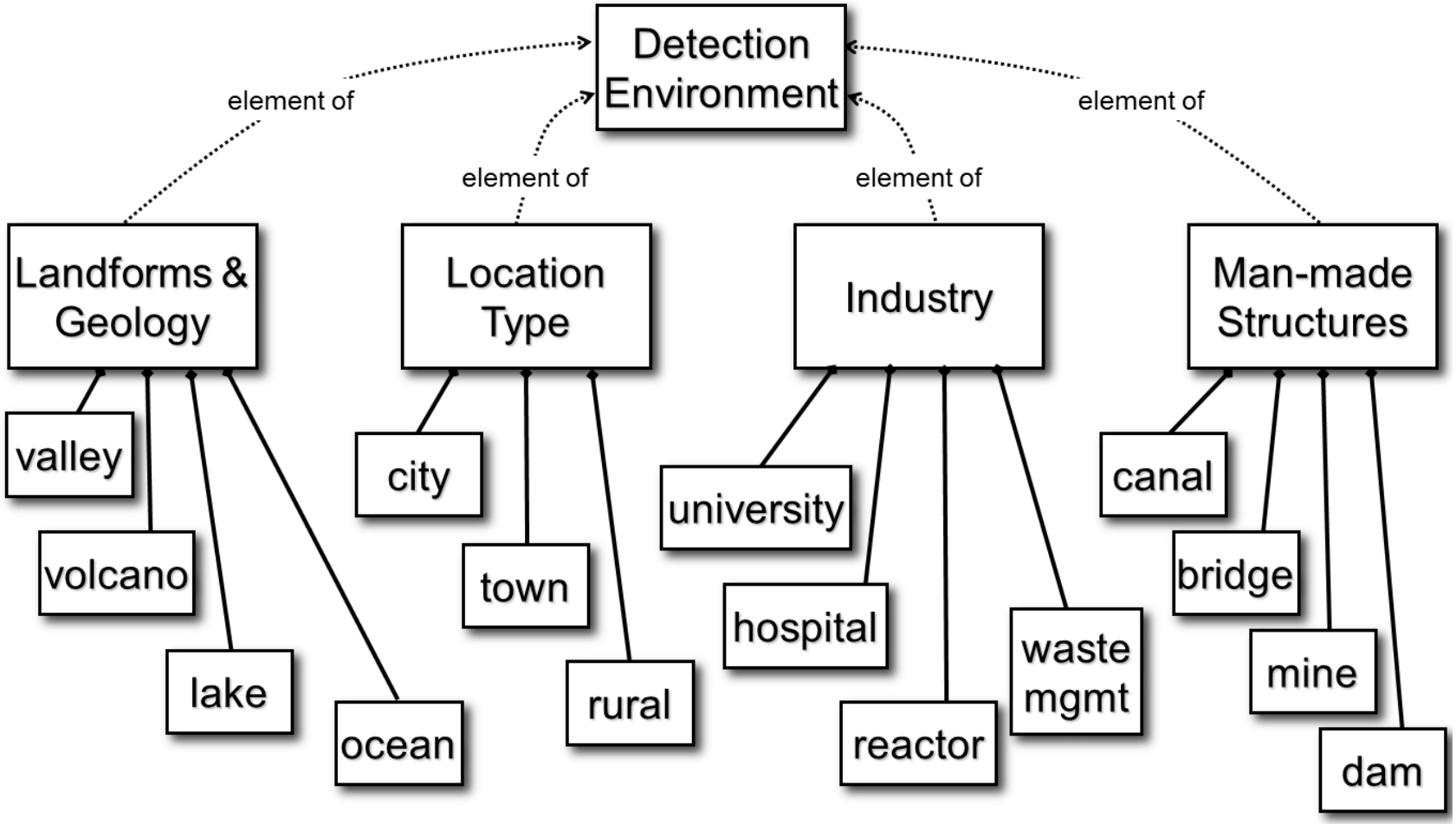
- Using a limited number of user input variables, expand the number and variety of scenarios generated
- Use ontologies to facilitate this process
- Manage scenario variables and data structure using latent knowledge encoded in ontologies
- Ontologies guide user interface construction and output narrative generation

Ontology-Driven Scenario Generator

Ontology based on BFO

- Overall development methodology based on
  Basic Formal Ontology
- A domain ontology was developed based on multiple sources
  - Interviews of SMEs
  - Field manuals, textbooks, etc.
- Domain Ontology:
  Special Nuclear Materials Detection Ontology (SNM-DO)
- Gathered ontologies describing geographic entities:
  General Ontology of Geographic Kinds (GOoGK)
- Ontologies developed using Simple Ontology FormaT (SOFT)

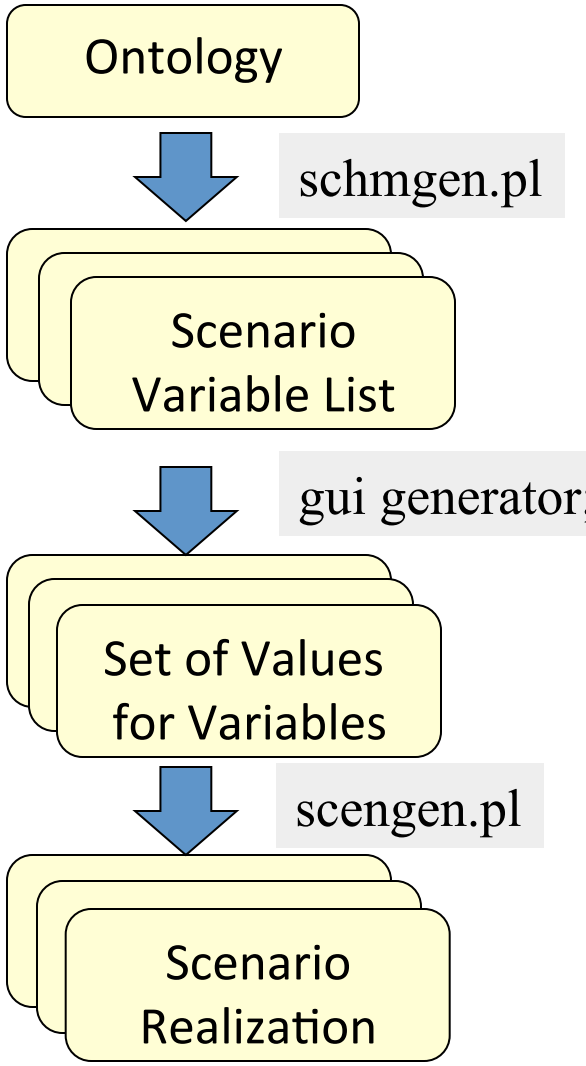
Special Nuclear Materials Detection Ontology (SNM-DO) - portion



Ontology-Driven Scenario Generator System Architecture

- **Ontologies support creation of a large number of scenarios from a limited set of user input**
- **Ontologies are used in various parts of data processing cycle**
  - SNM DO and supporting ontologies used to **configure** the interactive scenario generator.
  - Entities from ontologies used at the **configuration stage**
    - Link geodata sources and simulation models
    - Generate the GUI
  - At the **scenario generation stage** user input is
    - Received through the GUI
    - Used to construct the data by either retrieving it from
      - The matching location in the geodatabase
      - Running simulation models, if such data are not available

Levels of Abstraction in ODSG



ODSG is built around several ontologies stored in Simple Ontology FormaT (SOFT).

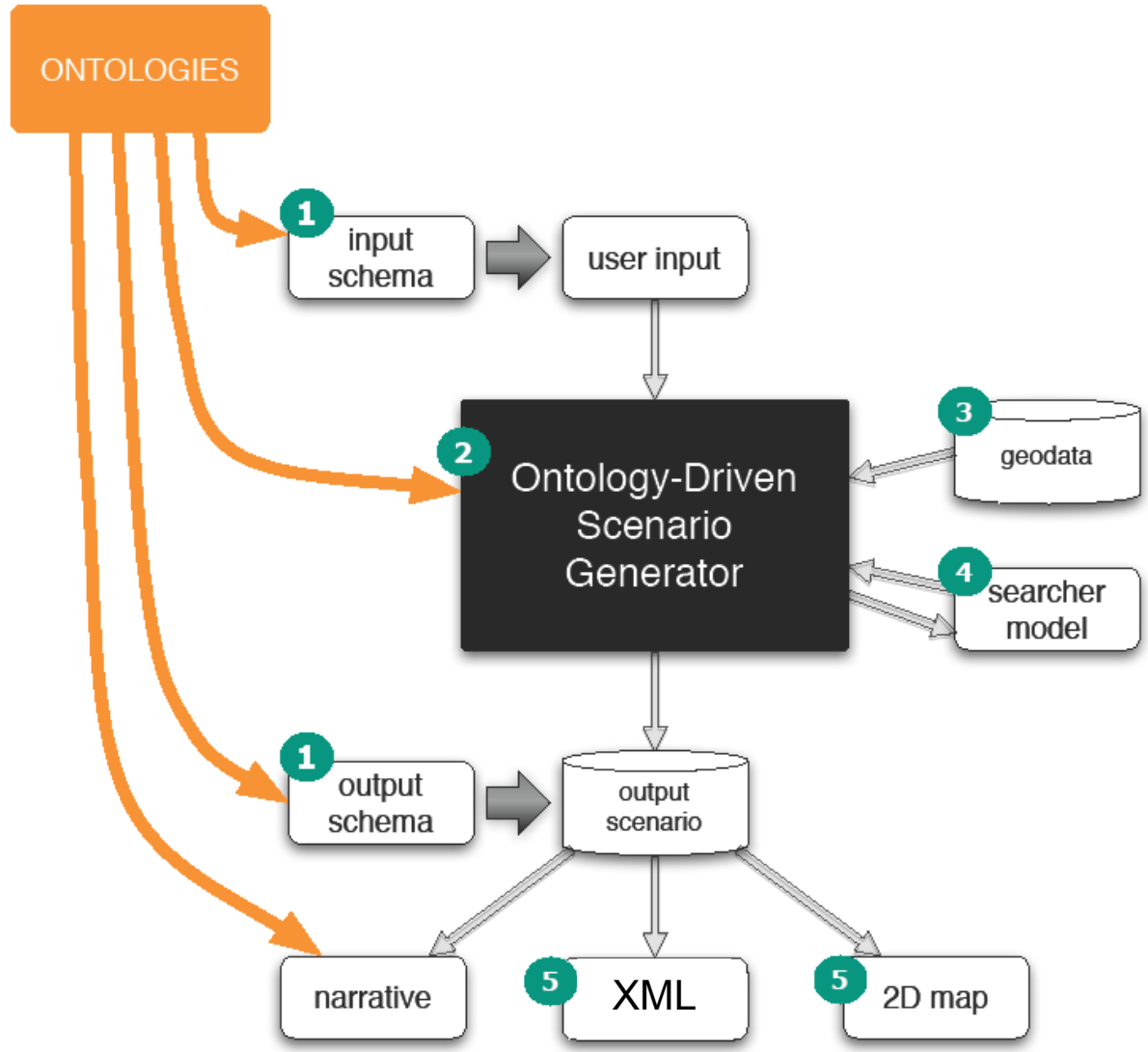
The variable list is created from ontologies using schema generator; GUI is generated from the variable list.

User enters variables through the GUI; a set of variable values is stored in the database.

Scenario generator creates multiple scenario realizations from the same set of values of the input variables.

How are ontologies utilized in the ODSG software

Ontologies used to control four code operations



Applications of ontologies in ODSG

Generate ODSG Application

- Manage and manipulate scenario variables
- Linking and matching with data sources ★
- Generate application interface

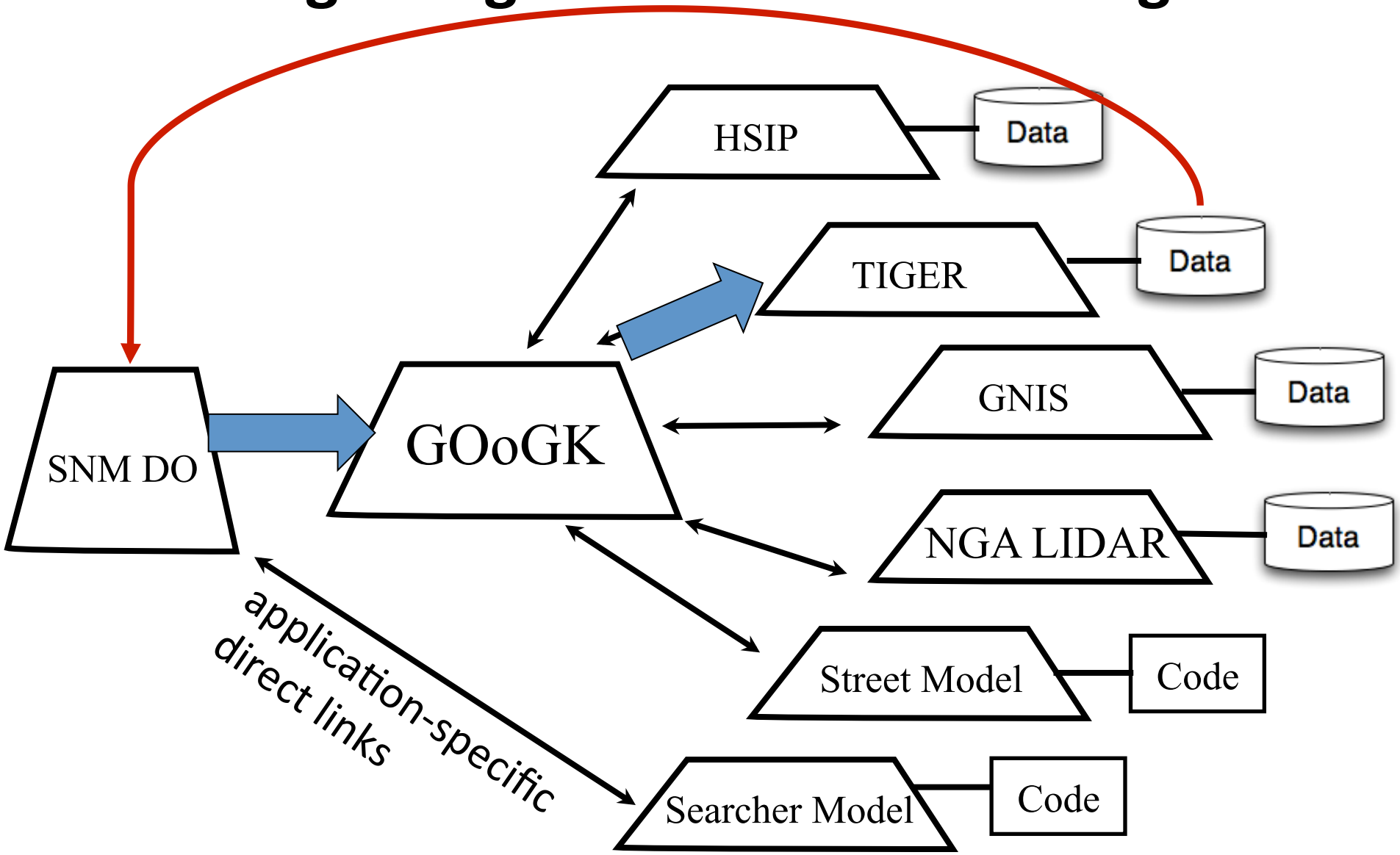
Generate Scenarios

- Inference missing data ★
- Interpretation and generation of natural text
- Document and track entities and relationships

Linking and Matching with Data Sources

- **Intermediate Ontologies**
  - Number of links is reduced in case of multiple versions of any of the ontologies
  - Convenient to have a common semantic model for the domain
- **Ontology Matching**
  - Matching between categories is necessary to link ontologies
  - Semi-automatic matching by similarity of category names
  - Manual verification

Matching Using Intermediate Ontologies



Reasoning new data from existing data and knowledge bases: Hospitals

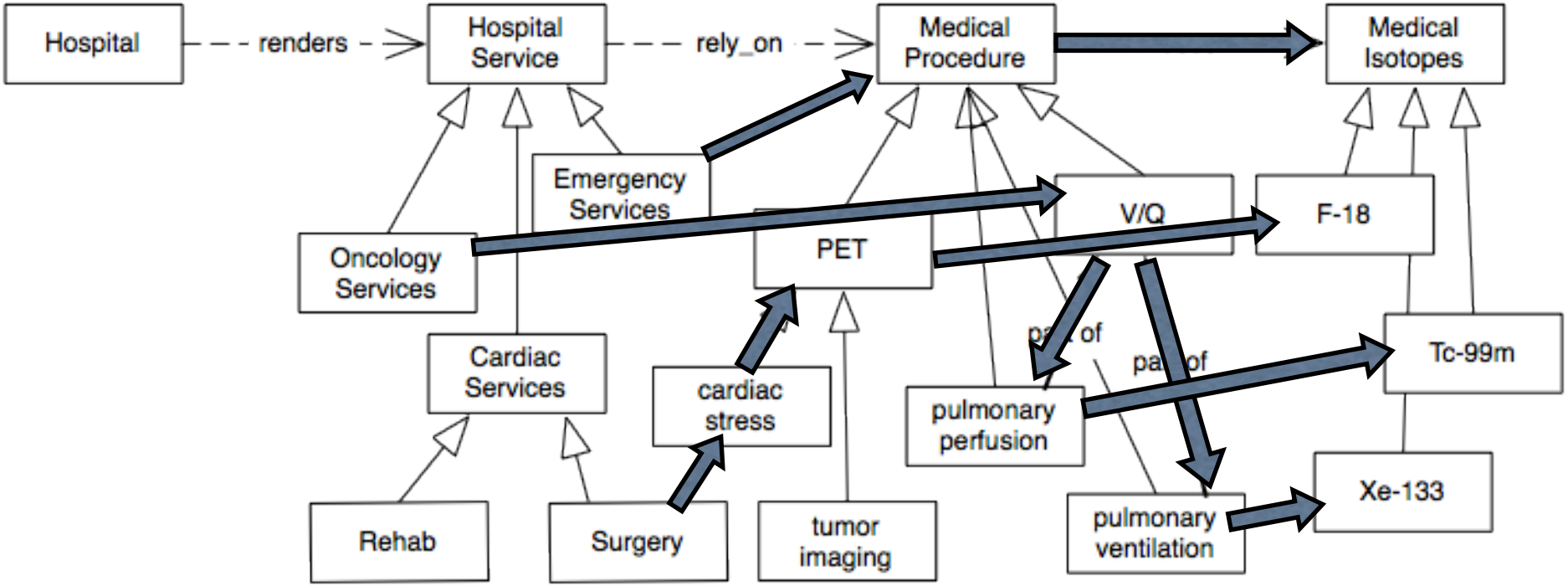
Purpose

- Inferencing from hospital and services and procedures provided to medical isotopes that are used in diagnosis and treatment
- Patients leaving this hospital might have received those medical isotopes

Data

- American Hospital Association (AHA) database

Hospitals: Inference Steps

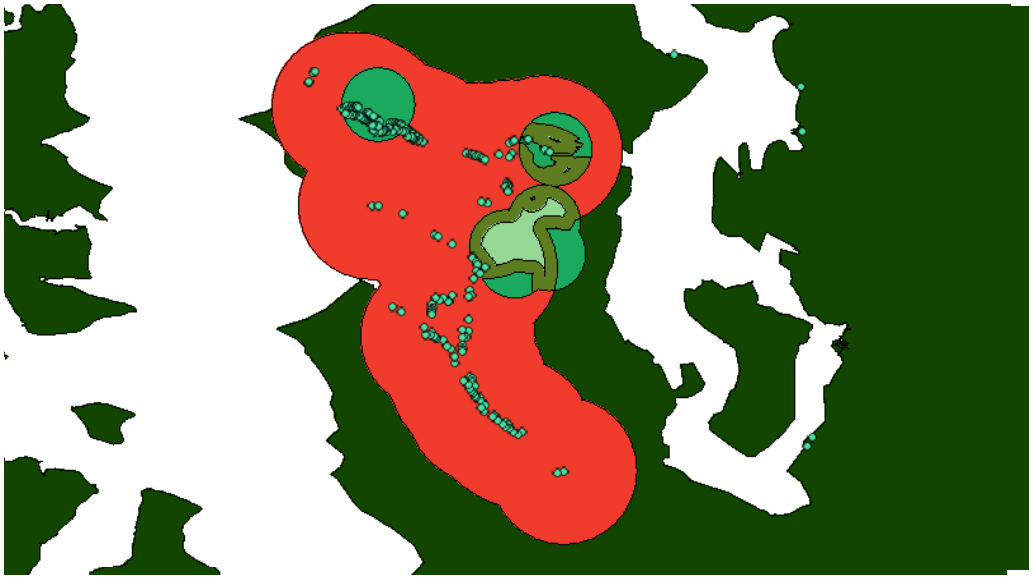


Hospital A *renders* **oncology services** which *rely_on* ventilation/perfusion (V/Q) procedures: **pulmonary perfusion** which *uses* Tc-99m and **pulmonary ventilation** which *uses* Xe-133. Patients exiting that hospital might be carrying these isotopes.

Candidate Region Creation

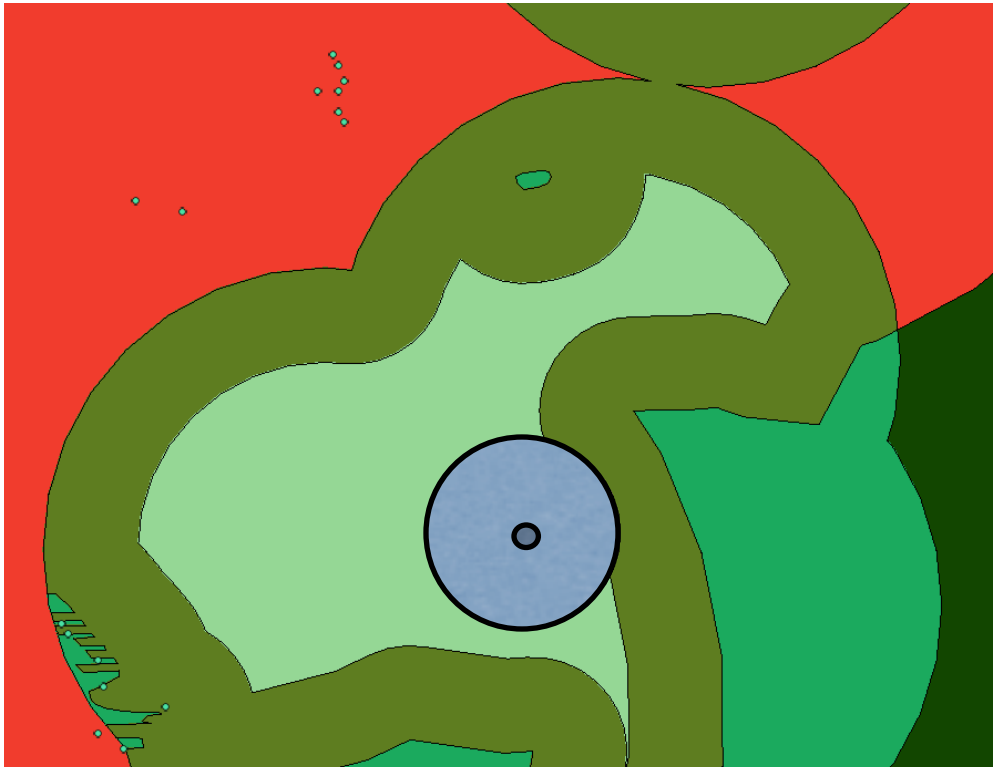
- Candidate region: area which satisfies the criteria specified by the user
- Example: urban setting in western U.S. within a mile from a hospital
- Scenario generation uses available geodatasets to find such area

1. Starting point: Continental US polygon
2. Clip by user-selected US Region
3. Clip by data availability mask
4. Clip by proximity criteria
   - ports
   - hospitals
5. Determine candidate region



Search Area Creation

1. Candidate region (light green) from previous step guaranties that all its points meet selection criteria for scenario setting
2. A random point is dropped into candidate region
3. A buffer of search area diameter is created around the point



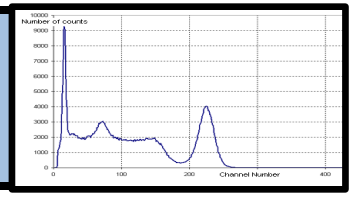
Clipping Data from Layers

- Features that overlap the search area are extracted from data source
- The structure of scenario database is created as specified in SNM-DO

Scenario Realization is Stored in Database

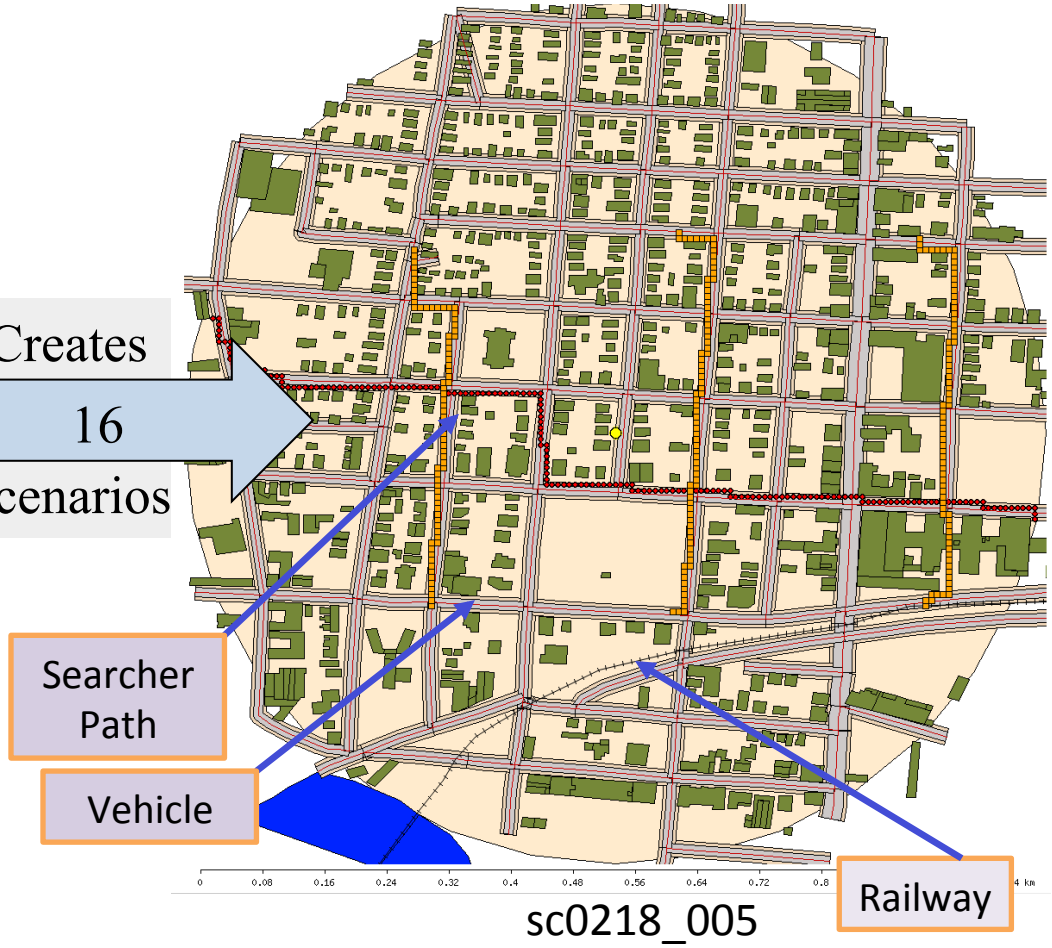
- Resulting scenario is persistently stored in relational database as several tables
- Typically contains a few hundred objects (street, rivers, building footprints, searcher and pedestrian walkpaths, etc.)
- Each object has a georeferenced geometry
- Scenario can be converted into XML, KML or other common formats using standard software

Ontology-Driven Scenario Generator

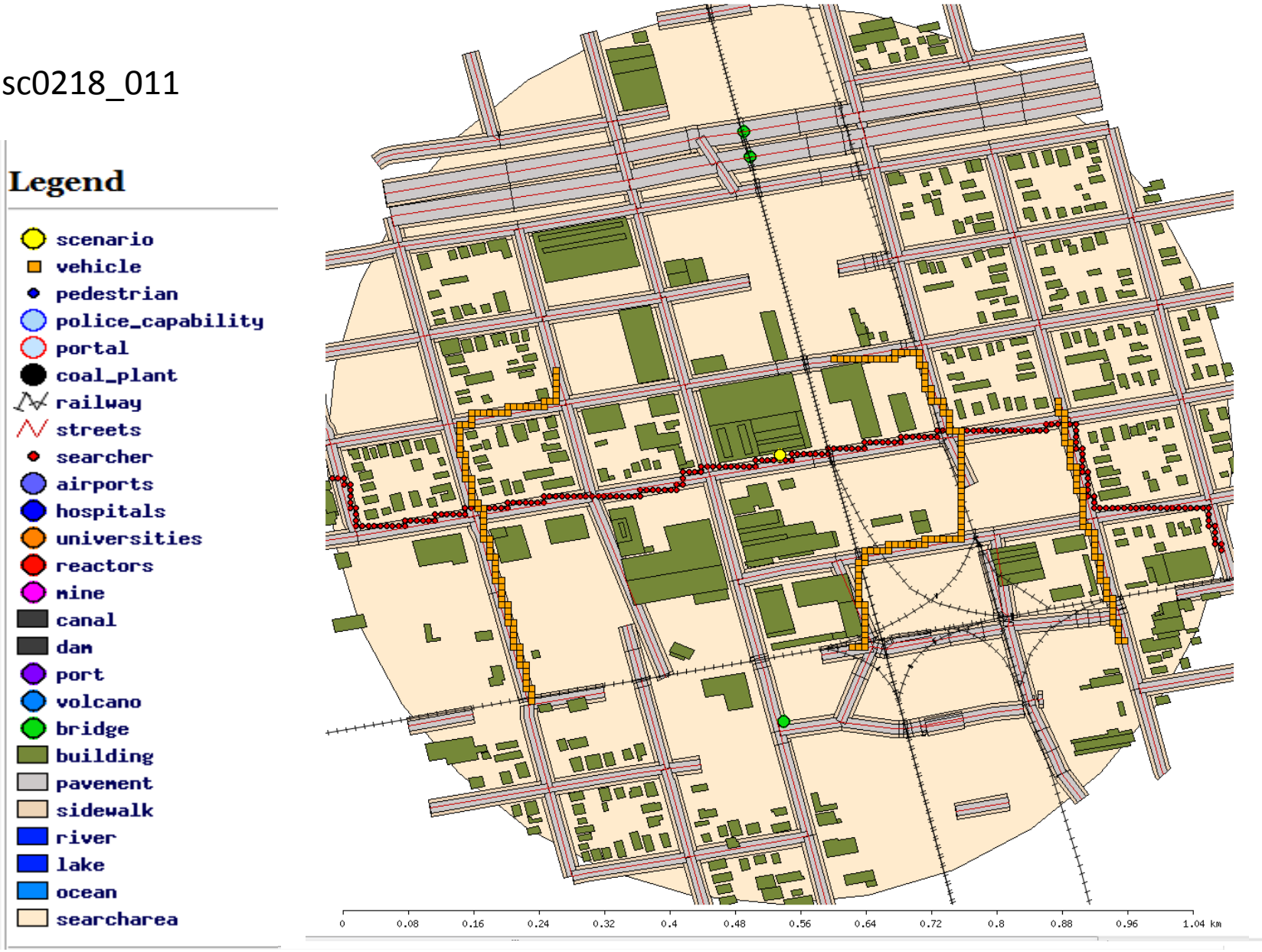


User Input Variables

Number of searchers	1		
Number of pedestrians	0		
Number of vehicles	3		
General US Region	New England		
Type of Detector	Handheld	**Material**	$LaBr_3$
Type of Search	Event-driven	By protocol	
Near search area	Railway	Port	



sc0218_011


Legend
scenario
vehicle
pedestrian
police_capability
portal
coal_plant
railway
streets
searcher
airports
hospitals
universities
reactors
mine
canal
dam
port
volcano
bridge
building
pavement
sidewalk
river
lake
ocean
searcharea
0
0.08
0.16
0.24
0.32
0.4
0.48
0.56
0.64
0.72
0.8
0.88
0.96
1.04 km

XML (based on KML) defined for developing 3D renderings of scenario

Collaboration with Randy Roberts (LLNL) and Paul Pope (LANL)

Example: Nashville, TN

```
<river>
    <nom>58540</nom>
      <Polygon>
        <outerBoundaryIs>
          <LinearRing>
            <coordinates>
              -86.776358000000002,  36.168611999999996
              -86.776488999999998,  36.168554999999998
              -86.776881000000003,  36.168386999999996
              -86.777012999999997,  36.168330999999995
              -86.777158999999997,  36.168534000000001
              -86.777355000000000,  36.168742999999999
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              -86.778885000000002,  36.171340000000001
              -86.778737999999990,  36.171399999999998
            </coordinates>
          </LinearRing>
        </outerBoundaryIs>
      </Polygon>
  </river>
```

Conclusions

- Created ODSG: a software environment that generates scenarios for testing algorithms for detection of SNM that
    - Takes as input very general set of variables
    - Creates wide variety of output scenarios based on this input
- Uses both domain-specific ontologies and latent-background knowledge
- Domain ontology, SNM DO, was built using subject-matter expert knowledge of the detection process for searchers on foot in an urban setting

Conclusions, Cont'd

- Software relies on ontologies to
  - Configure the software architecture
  - Drive inferencing based on ontological reasoning
- ODSG created an expanded number and variety of scenarios generated from a single set of user input.
- Presented specific example set of input used to create 16 scenarios
- Applications such as ODSG show the importance of incorporating ontologies into software frameworks for generation of scenarios