RESEARCH & INNOVATION
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The iCity Ontology and Supporting Visualizations

How do we understand integrated transportation and urban systems? An ontology approach with visualization tools.

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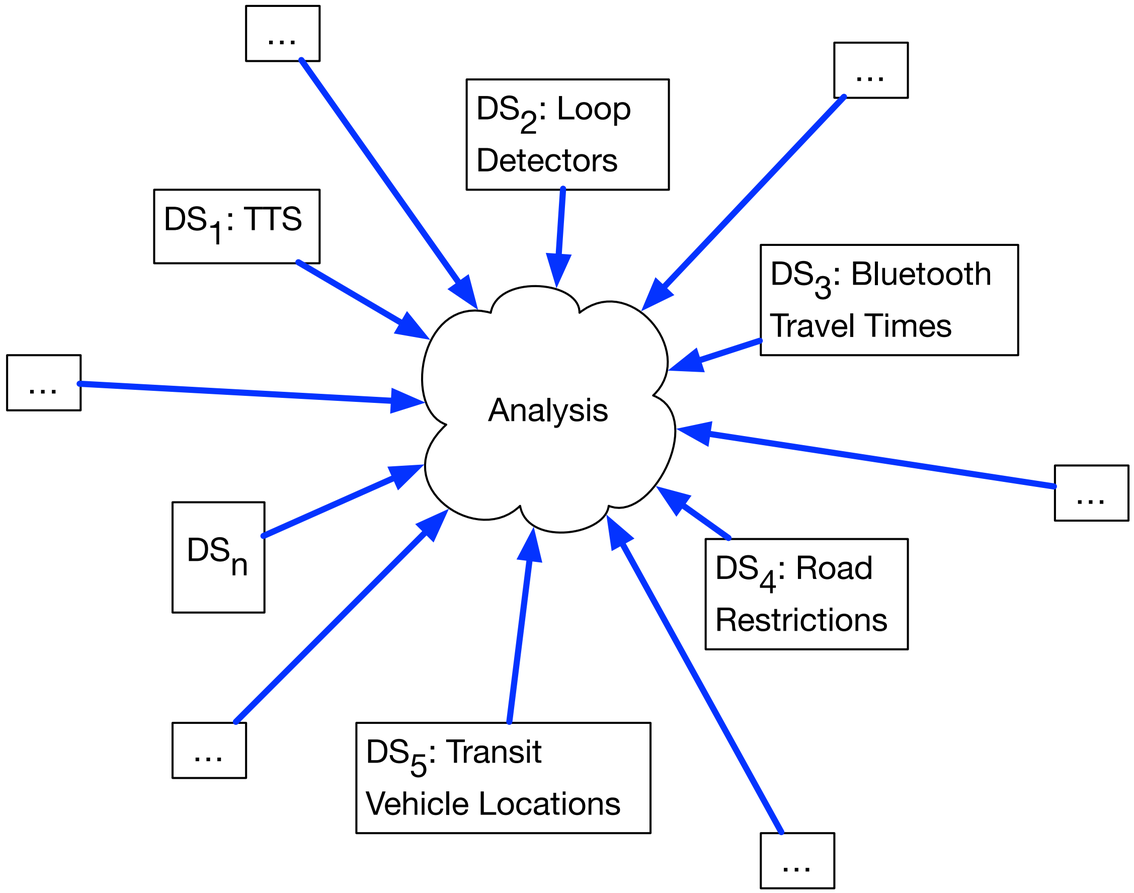
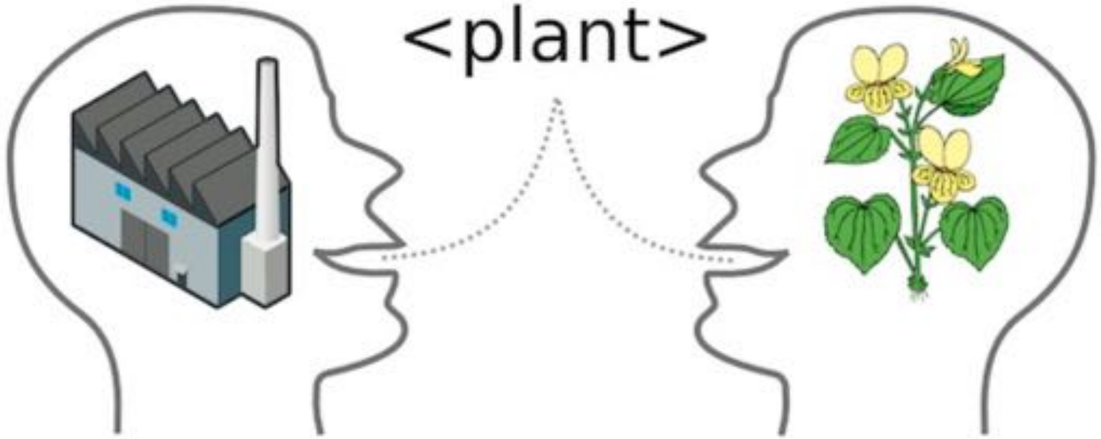
Transportation and urban systems: a morass of data

- Sensors, studies, simulations, …
- Households, transportation networks, vehicles, trips, …



Challenge: semantic interoperability

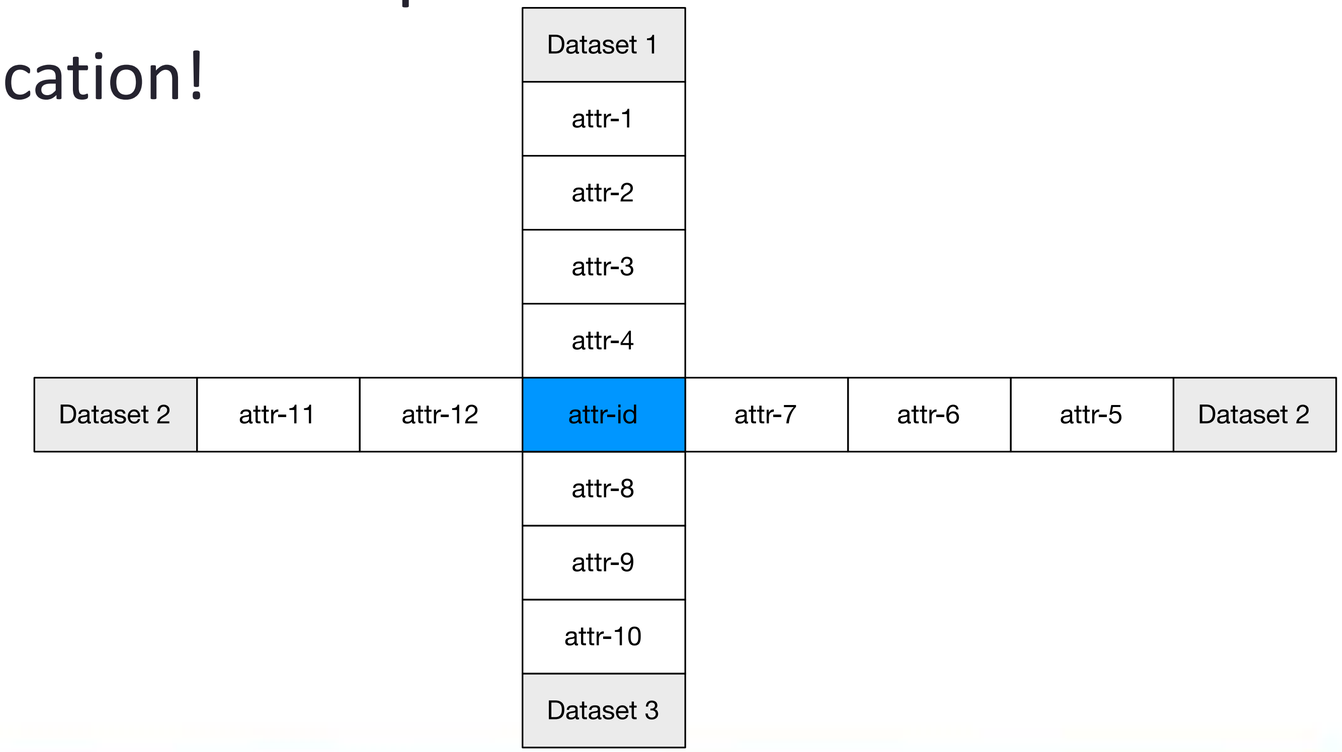
- Ability of computer systems to exchange data with unambiguous, shared meaning.



- A requirement for machine reasoning, knowledge discovery, and data federation across information systems.

The independence fallacy

- Shared attribute(s) identified and used for merging
- Other attributes are assumed to be independent of one-another
  - This is often an oversimplification!



Semantic Interoperability

Toronto

ID	Creation Date	Service Request Name
TO_Request1	01-02-2010 10:35:03	Missing/Damaged Signs

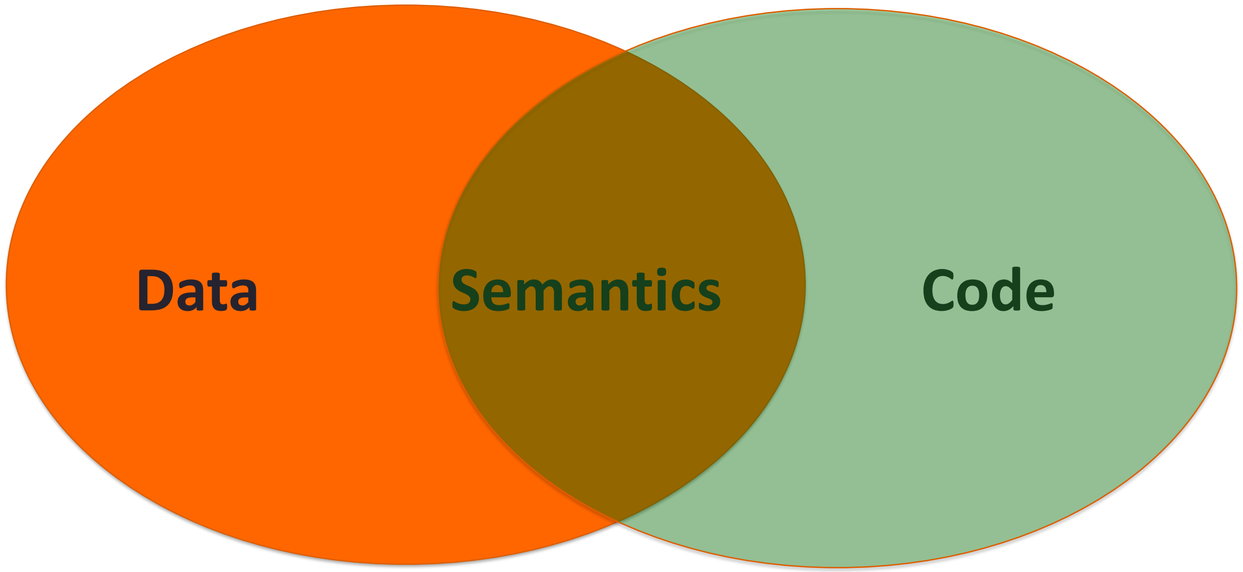
311

ID	Division	Section	Service Request Name	Problem Code
TO_Request1	Transportation Services	TMC – Signs & Markings	Missing/Damaged Signs	SAM-01

New York

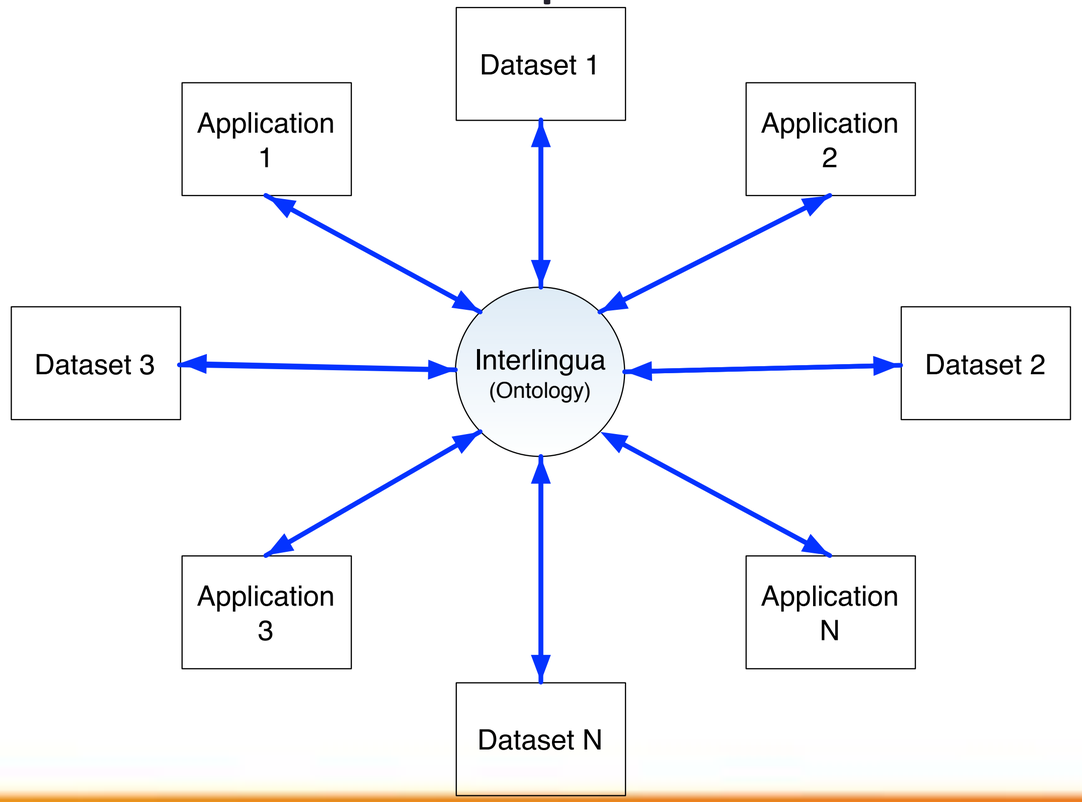
ID	Date	Agency	Complaint Type	Descriptor
NYC-Request1	4/30/2013 12:00:00AM	DOT	Street Sign – Damaged	Stop

Source of the problem



Solution: an ontology for urban informatics

- Addressing the challenge of semantic interoperability with a formal representation of transportation and urban systems: **an ontology**.



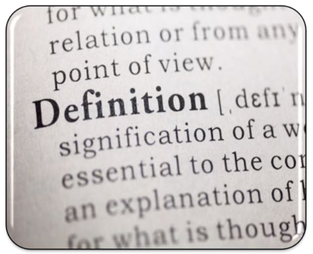
What is an ontology?

- (More than) a reference model for the domain. An ontology answers the questions:
  - What are the core concepts and properties of the domain (transportation and urban systems)?
  - What are the key distinctions?
- A precise, reusable, formal (written in a logical language) representation that supports:
  - Integration
  - Automated deduction

The ontology approach

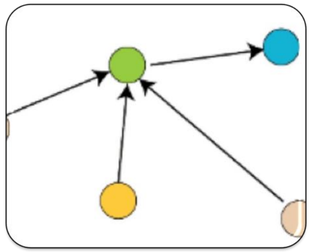
Micro-Theory

- Axioms/Rules
- Deduction – answering questions



Definitions and Constraints

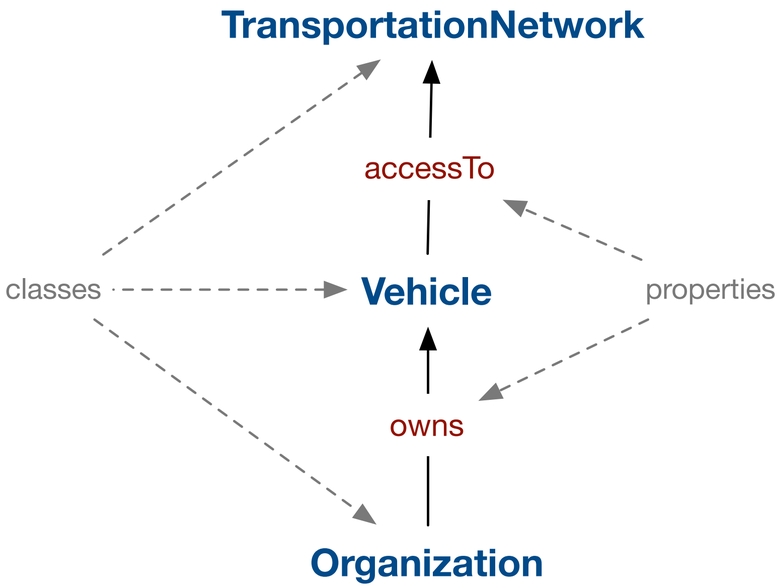
- Class Definitions (in Logic)
- Automated classification

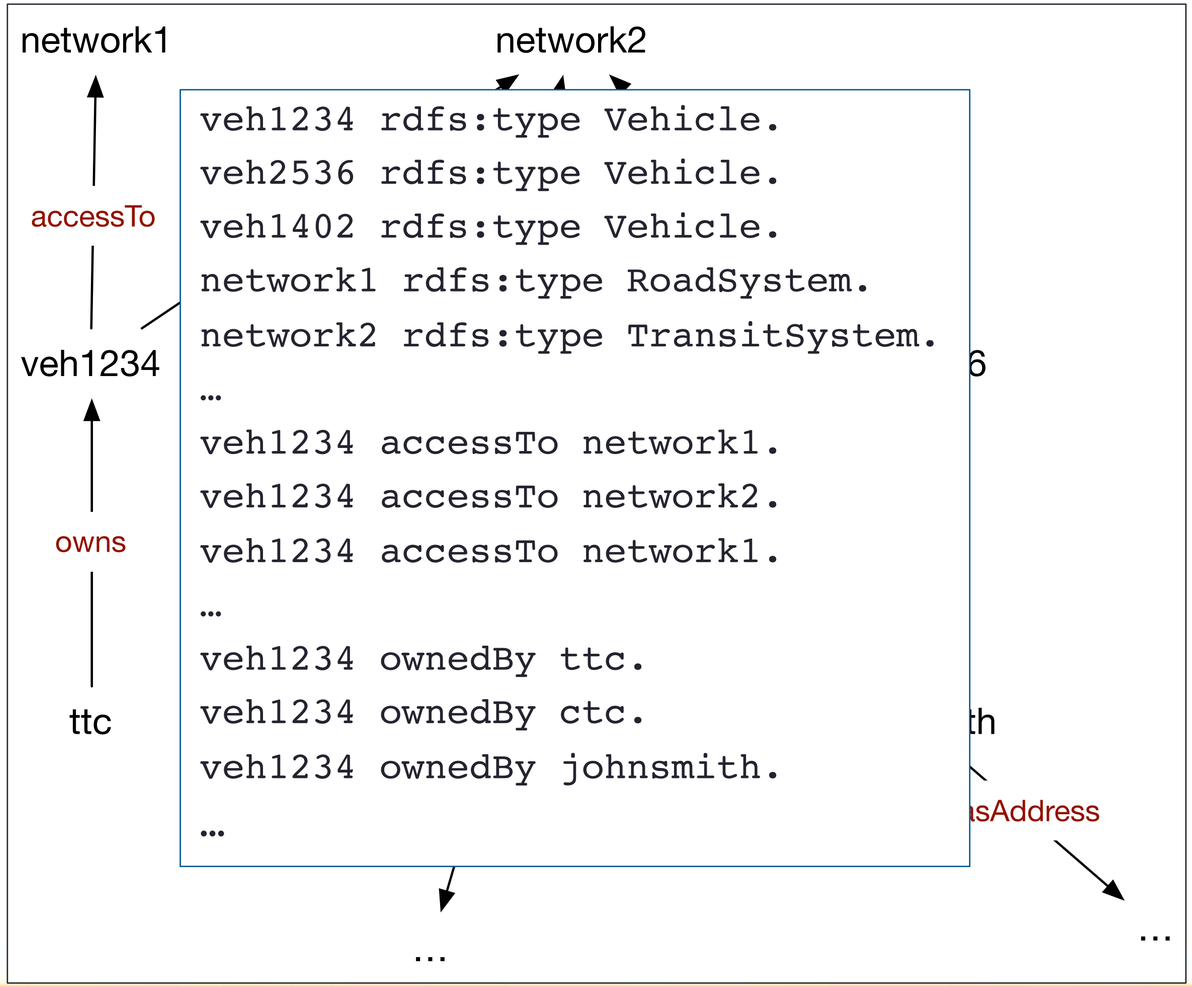


Knowledge Graph

- Classes and Properties
- Taxonomy and Inheritance

Example knowledge graph





Example definitions and constraints

Vehicle

∃ accessTo.RoadSystem

TransitVehicle:

TransitVehicle≡ Vehicle ⊓ ∃accessTo.TransitSystem

TransitVehicle ⊑ ¬(HouseholdVehicle)

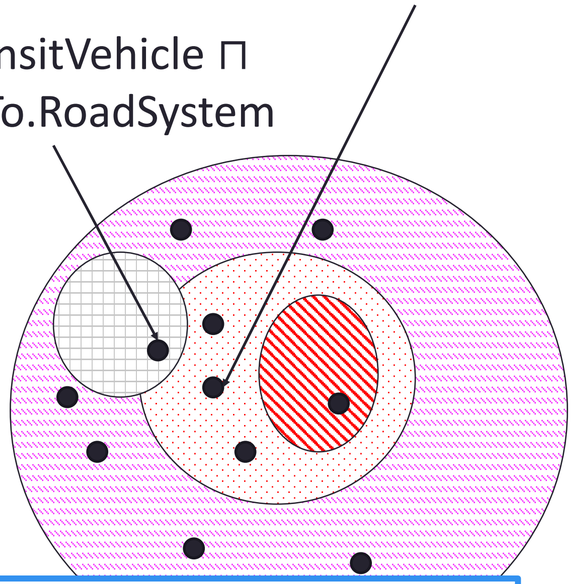
HouseholdVehicle:

HouseholdVechicle≡ Vehicle ⊓ ∃ownedBy.Person

HouseholdVehicle ⊑ ¬(TransitVehicle)z

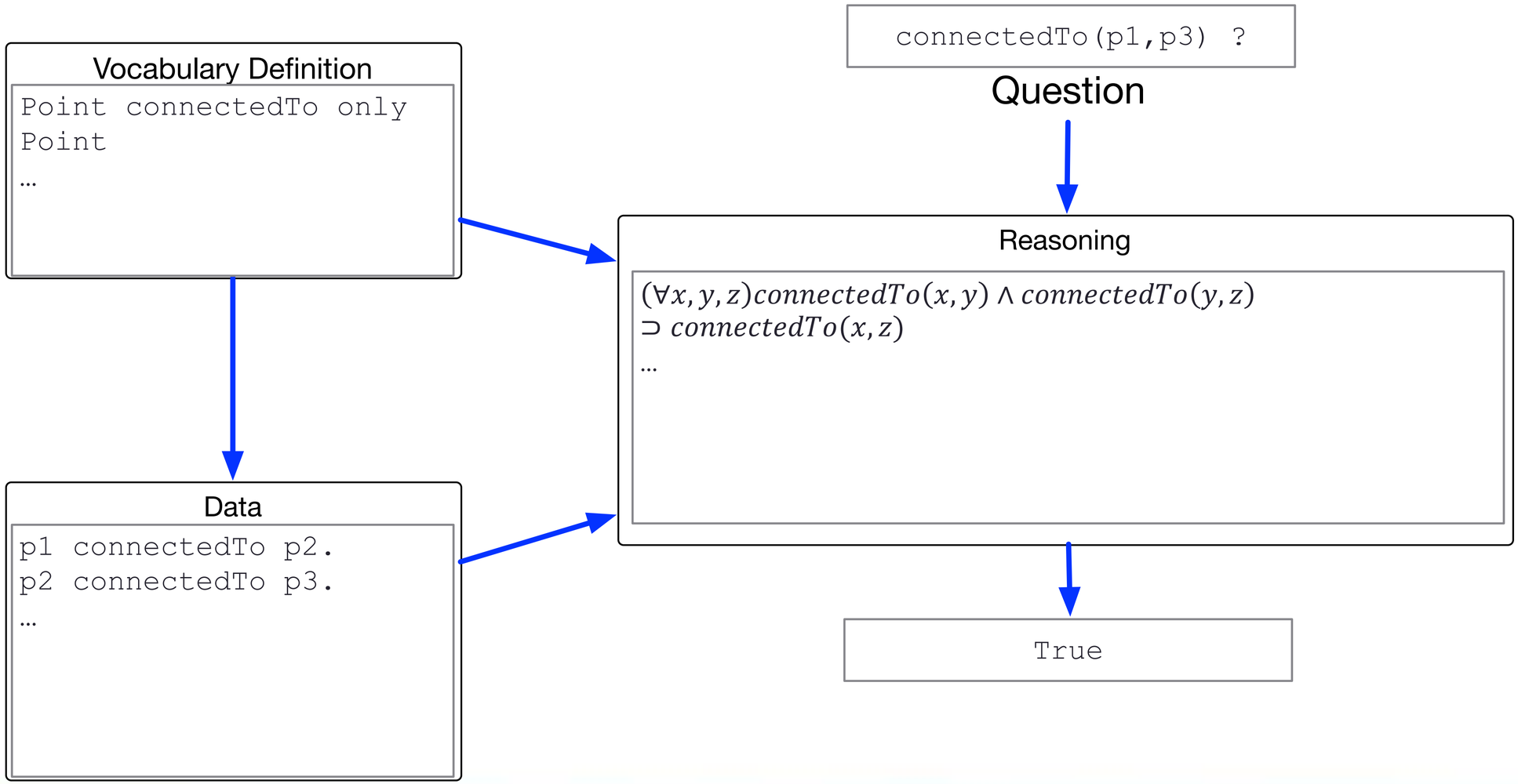
CommercialVehicle ≡ Vehicle ⊓ ∃accessTo.RoadSystem ⊓ ¬(TransitVehicle) ⊓ ¬(HouseholdVehicle)

Bus≡ TransitVehicle ⊓ ∃accessTo.RoadSystem

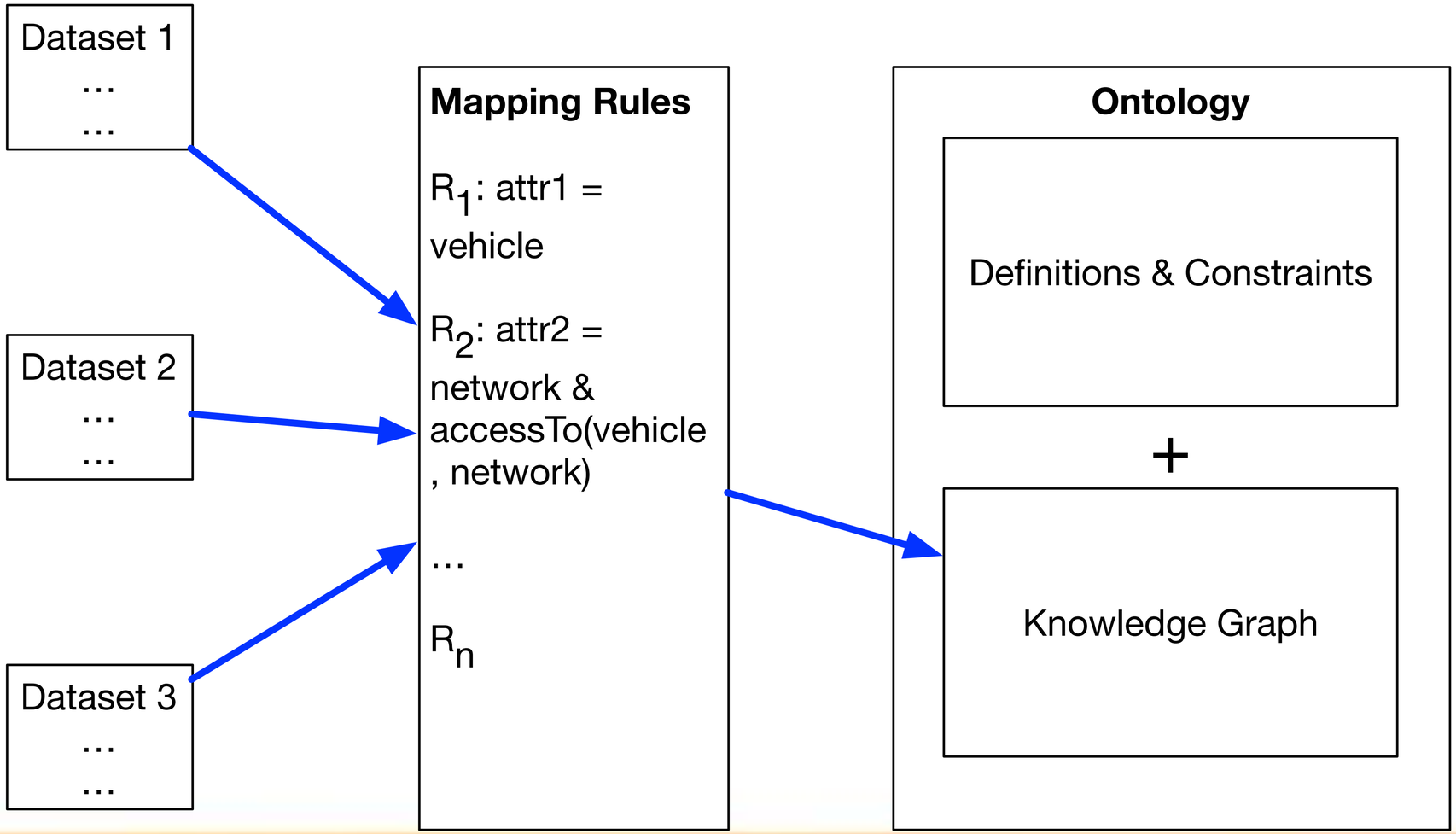


Automatic classification of instances

Beyond queries & classification: inference



Implementation: how does it work?



Semantic mapping example

Transit Agency Vehicle Location Feed

Vehicle_ID	Route	long	lat	Time
Veh1234	501	43.72053137	-79.52223983	01-Sep-2017 05:20:20
…				

Freight Agency Fleet Records

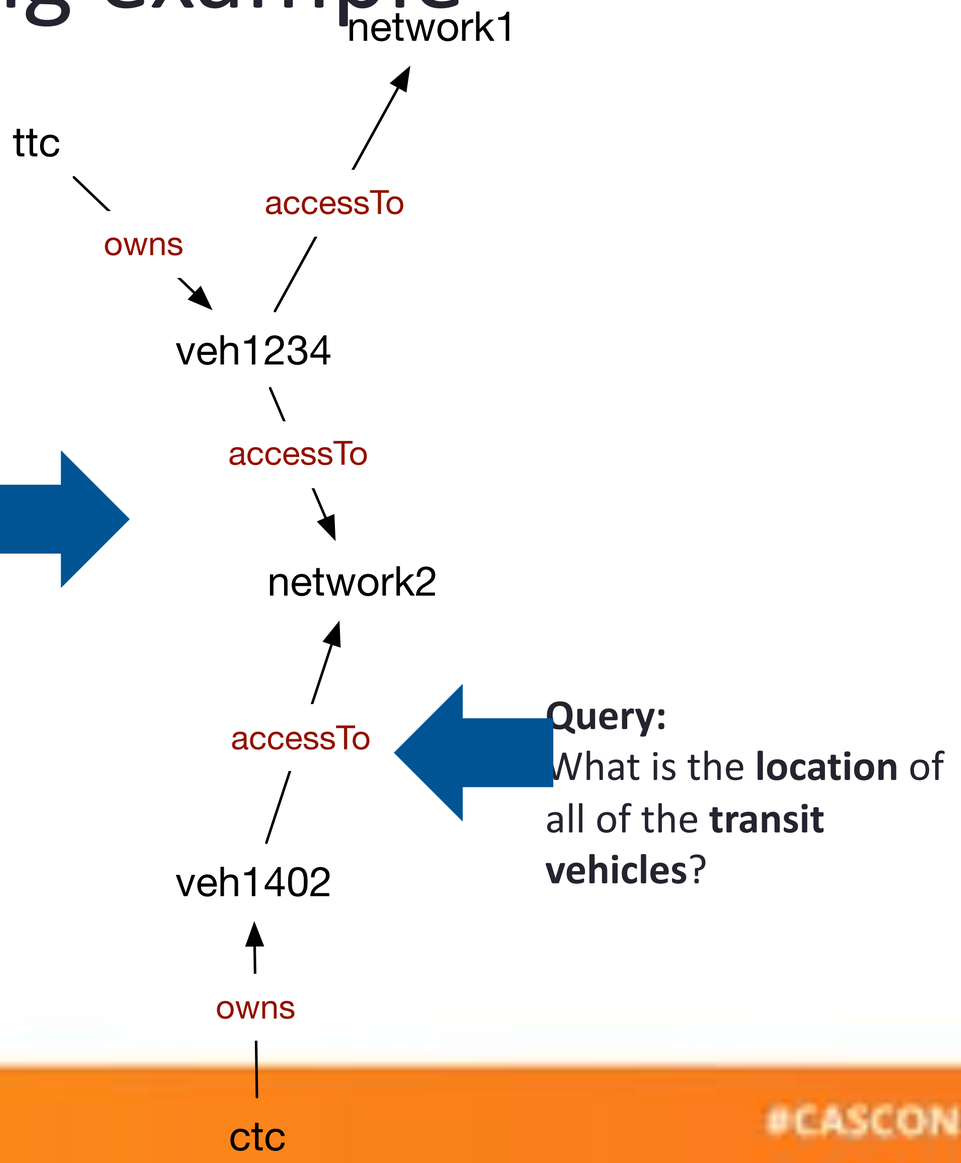
Carrier	location	Driver	recorded
Veh1402	44.72053137, -76.52223983	Al-cooper	01-Sep-2017
…			

Mappings:

Vehicle_ID → Vehicle

Carrier → Vehicle

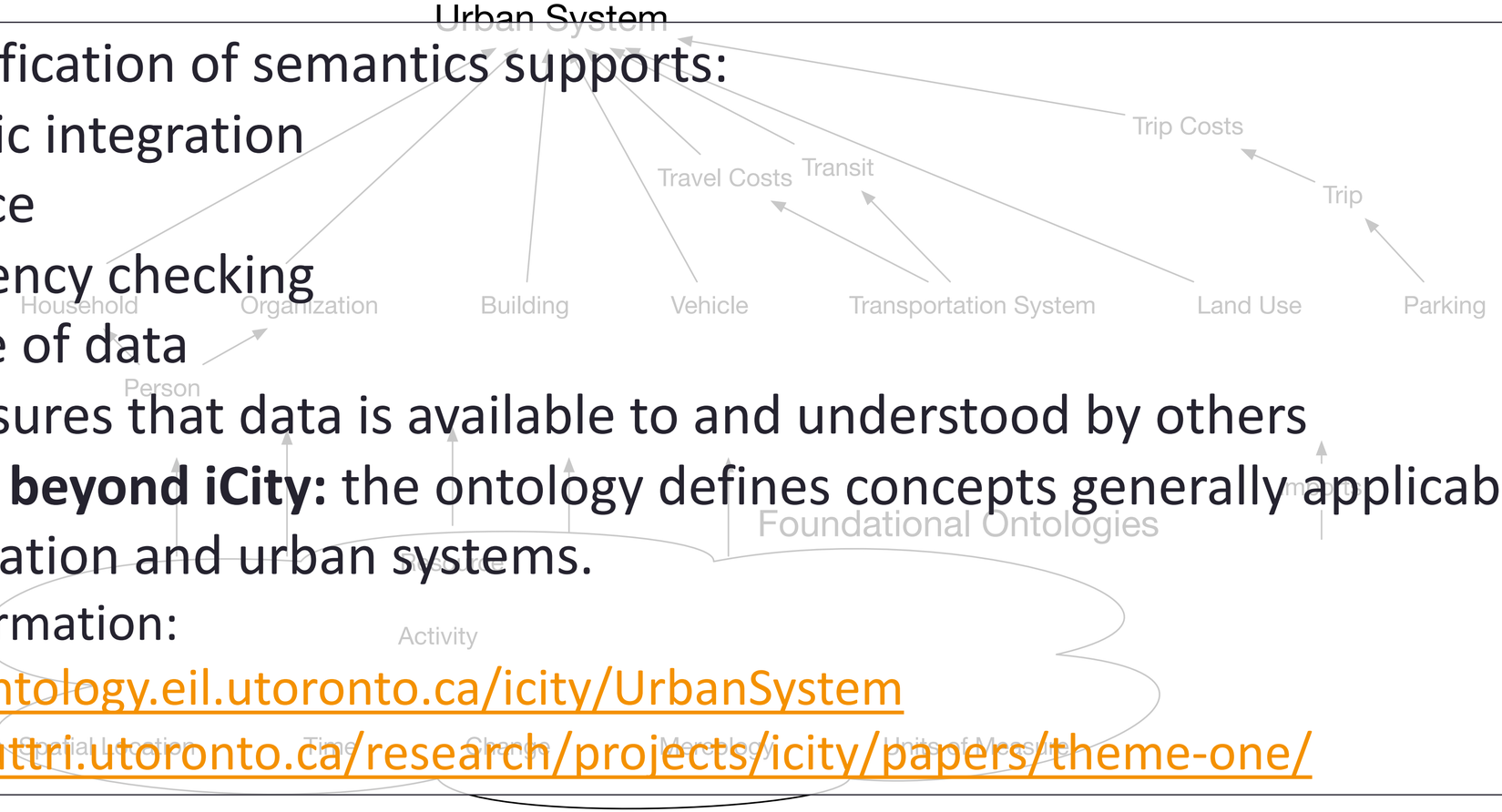
…



Query:
What is the **location** of all of the **transit vehicles**?

The iCity Ontology

- Explicit specification of semantics supports:
  - Semantic integration
  - Inference
  - Consistency checking
  - (Re-)use of data
    - Ensures that data is available to and understood by others
- **Applications beyond iCity:** the ontology defines concepts generally applicable for transportation and urban systems.
- For more information:
  - http://ontology.eil.utoronto.ca/icity/UrbanSystem
  - https://utri.utoronto.ca/research/projects/icity/papers/theme-one/



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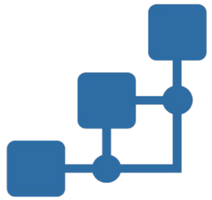
Visualization of the iCity Ontology

SEMANTIC GRAPHS



The iCity Ontology

Complex role-relation **association** between multiple ***concepts*** with multiple ***attributes***

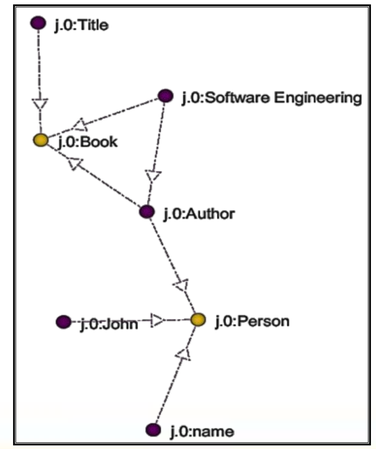
Network Graph

An effective way to represent the **complex dynamism** of Semantic Knowledge Base

Schema

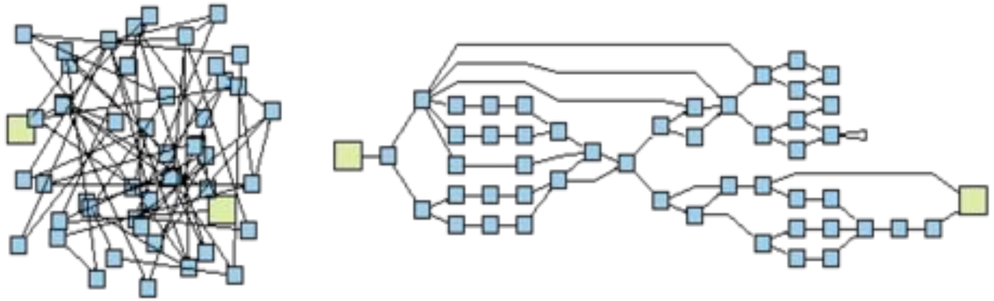
```
<rdf:RDF
    xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
    xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
    xmlns:j.0="urn:ocadu.ca/">
  <rdfs:Class rdf:about="urn:ocadu.ca/Person"/>
  <rdfs:Class rdf:about="urn:ocadu.ca/Book"/>
  <rdf:Description rdf:about="urn:ocadu.ca/name">
    <rdfs:range rdf:resource="http://www.w3.org/2000/01/rdf-
schema#Literal"/>
---
</rdf:RDF>
```


Graph



DESIGN CHALLENGE

Graph Drawing Layout

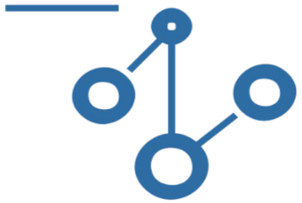


Structure of the graph can only be **understandable**, if it is in certain **readable layout**

Research Theme

- To understand the Highly **Complex**, **Dynamic** and **Scalable** *iCity Ontology*, there's an essential need to develop a **visual framework** supporting an aesthetically appealing **graph layout**
- **Visual Interaction** and **exploration** **of** *iCity Ontology* to understand the **semantics** behind complex role-relation associations in the form of **knowledge network graph**

SOLUTION BREAKDOWN



Ontology Visualization Technique

- A visualization technique is needed, to **visualize** *iCity ontology* **complex** structure in **directed network graphs**

Graph Drawing Layout

- Visual **exploration** and **interaction** with *iCity Ontology* through proper **graph drawing layout**
- Should **preserve** the **aesthetic** measures for **clarity**

Scalability & Performance

- Highly **scalable**, computationally **efficient** and **expressive** in terms of visualizing *taxonomy*, *inheritance,* *micro-theory* (axioms/rules and inferences…)

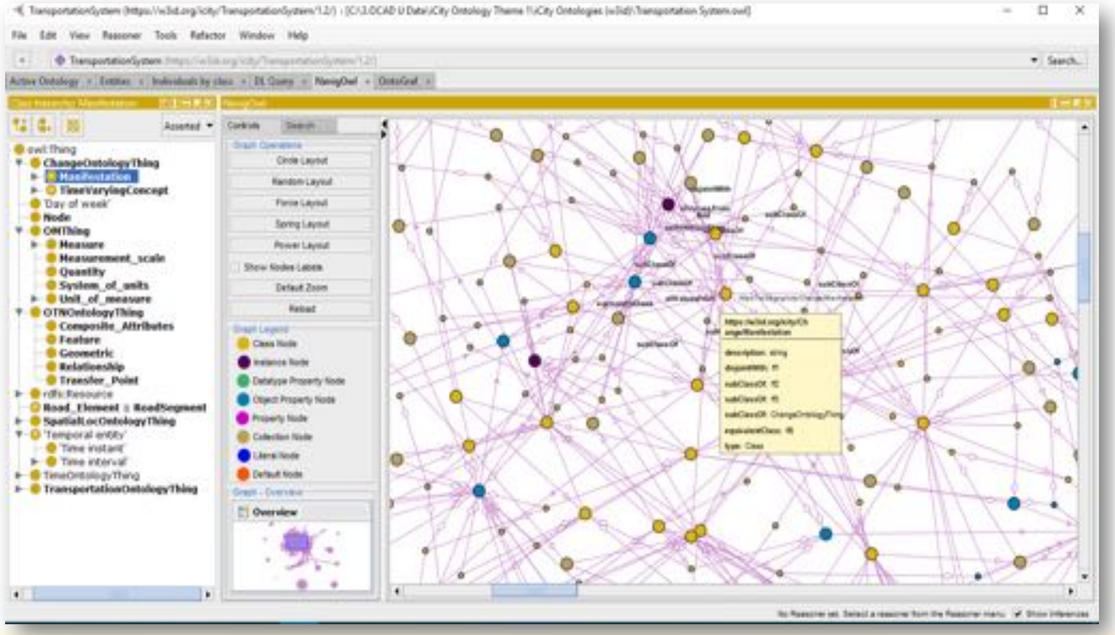
PROPOSED METHODOLOGY (1/2)

NavigOWL
A Tool for Exploring Semantic Nets!

- Native support of **Multi-Layered**, **Multi-Clustered**, **Power-Law** based **improved** *force-directed* graph drawing layout

protégé **Plug-in**

- *UoT* Researchers developing *iCity Ontology* in *Protégé* (Ontology Editor) and can **natively visualize** current ontology through *NavigOWL* plug-in

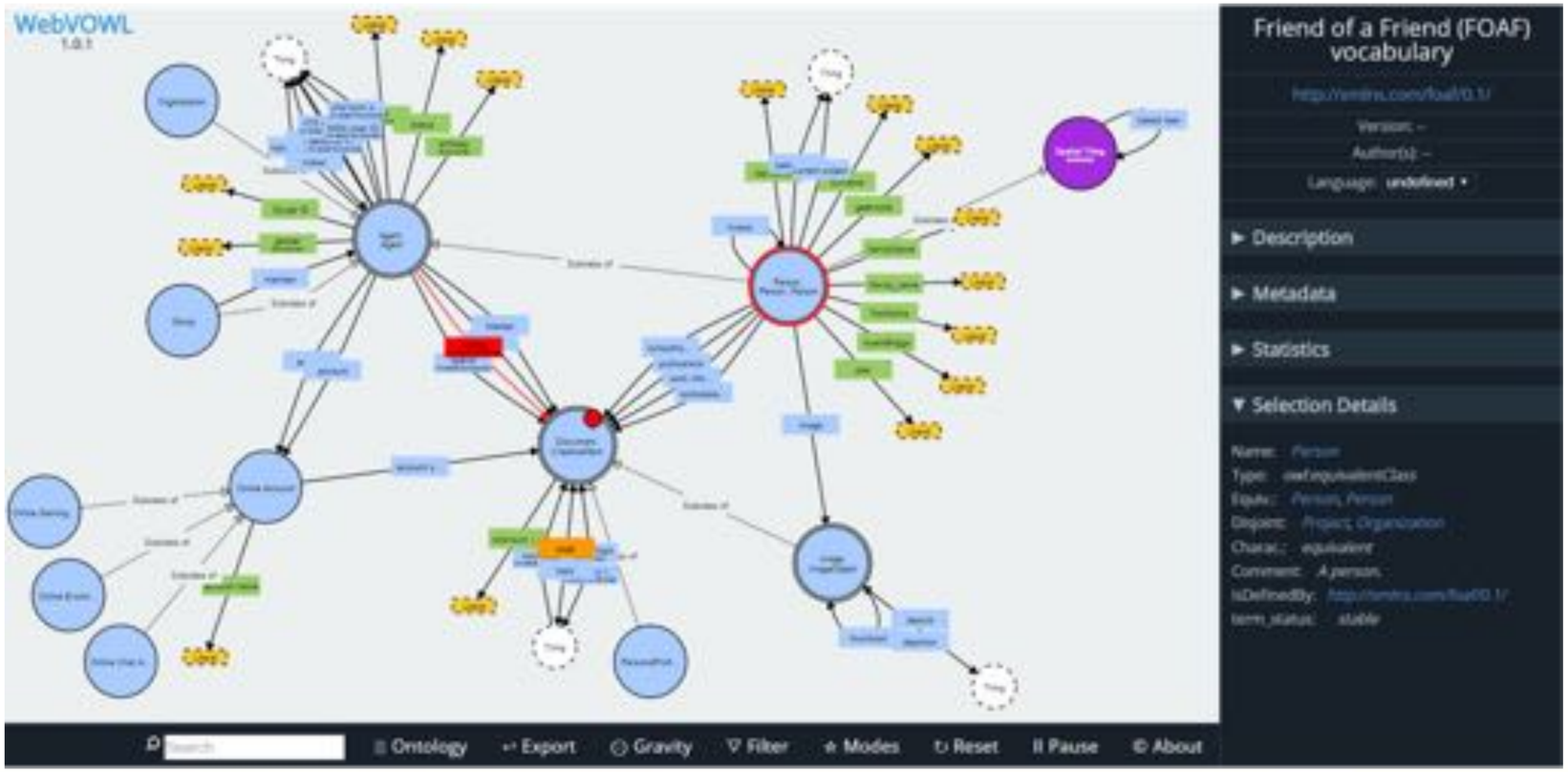


PROPOSED METHODOLOGY (2/2)

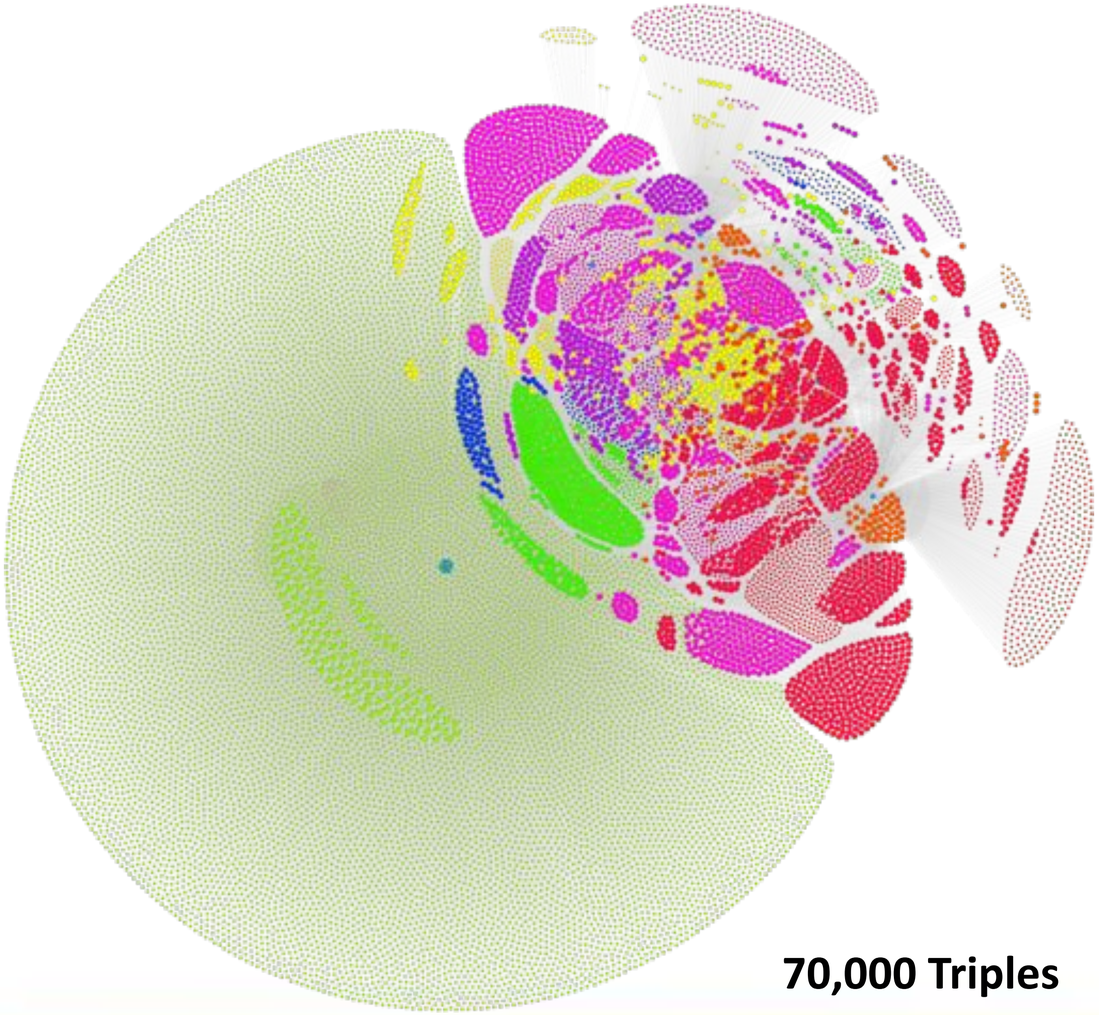
WebVOWL: Web-based Visualization of Ontologies

- Open-Source tool for **interactive visualization** of Ontologies, with native implementation of **Force-Directed** *graph layout*

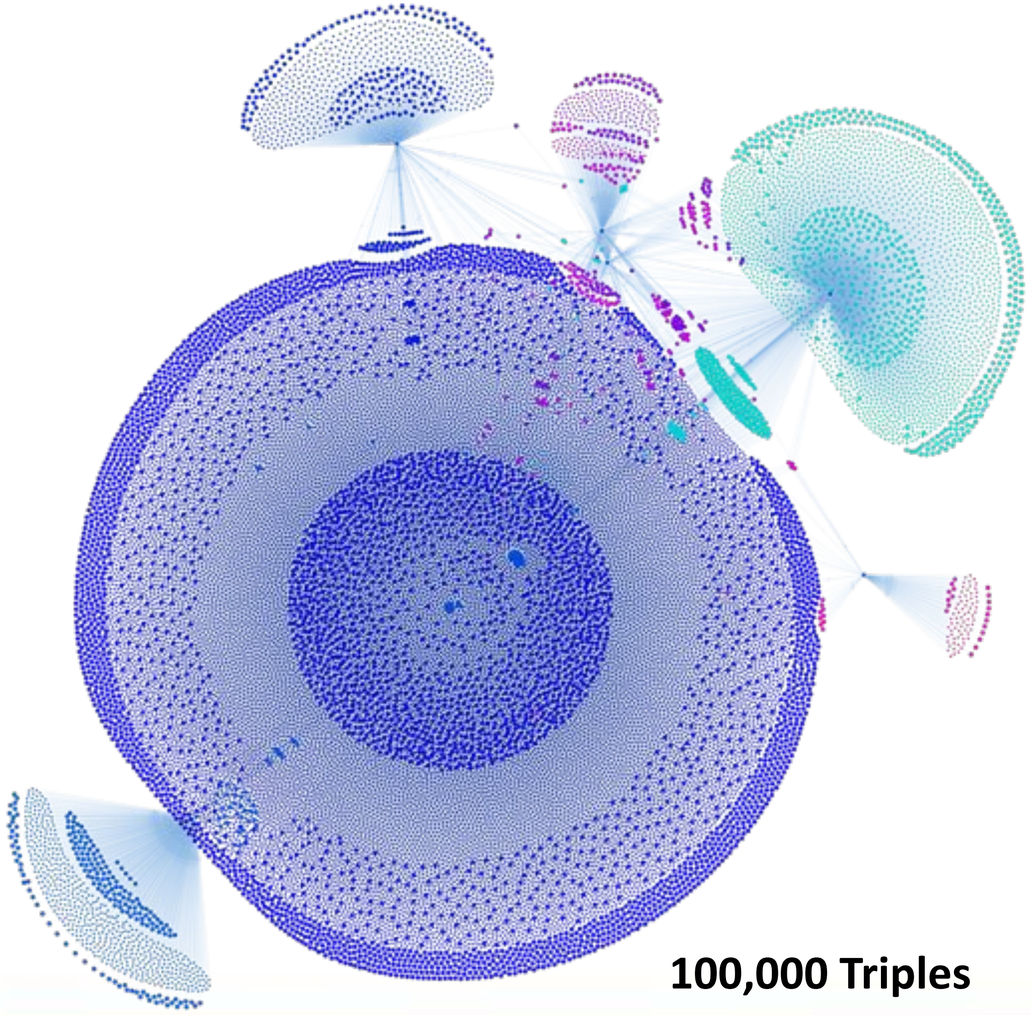
- *UoT* Researchers using WebVOWL tool for visualizing the initial ***iCity Ontology* Models**, by leveraging the native force-directed graph layout



SHOWCASE: Power-Law based Graph Drawing Layout

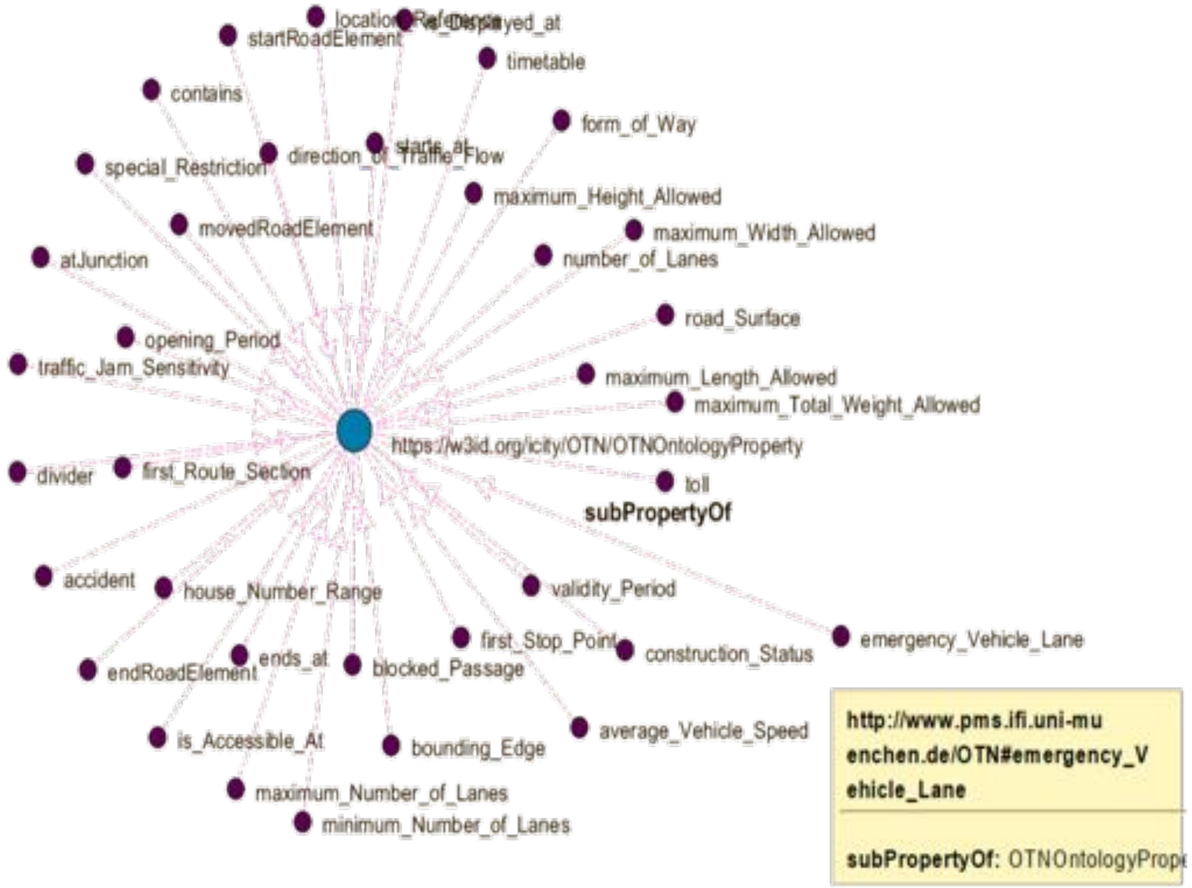


70,000 Triples



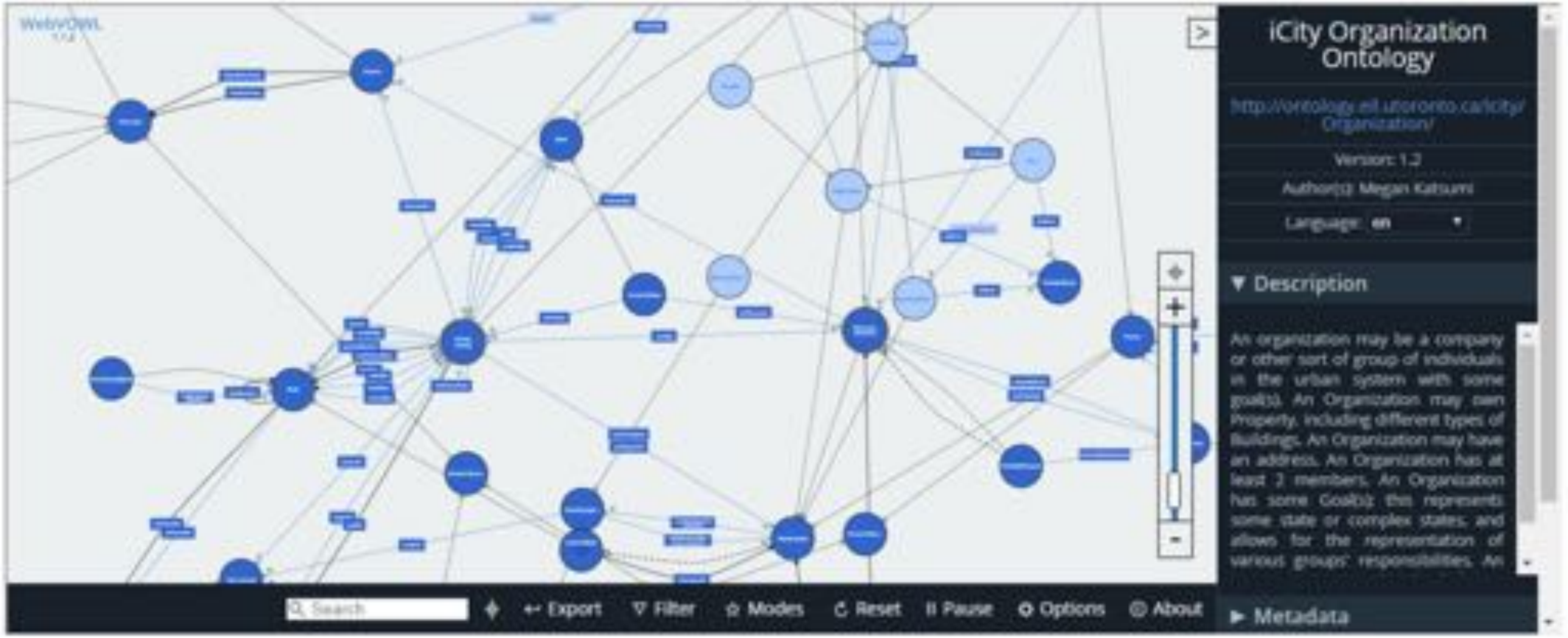
100,000 Triples

PRELIMINARY RESULTS - NavigOWL (1/2)



In-Depth Visual Analysis of *iCity Transportation System* Ontology

PRELIMINARY RESULTS - WebVOWL (2/2)



In-Depth Visual Analysis of *iCity Organization* Ontology

FINAL THOUGHTS

VISUAL INTERFACE

Initial **Visual Interface** for **exploration** and **interaction** of *iCity ontology* for better understanding the **dynamism** and **complexity** by leveraging *NavigOWL graph Layout*

WEB INTERFACE

Proceeding with web-based interface of WebVOWL with integrated **improved graph layout** for online **accessibility** and **usability** for other *iCity* groups and stake-holders

ENRICHMENTS

Expressive representation of *micro-theory*, *axioms*/*roles* with support of **Visual Filters** and **Adaptive View** to display "*Significant*" sub-graph(s)

QUERY INTERFACE

Visualization of **Query Results** on *iCity Ontology* with **embedded view** in other *iCity Dashboards* for **reusability** and **extendibility**

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THANK YOU!