Multi-INT Complex Event Processing using Approximate, Incremental Graph Pattern Search

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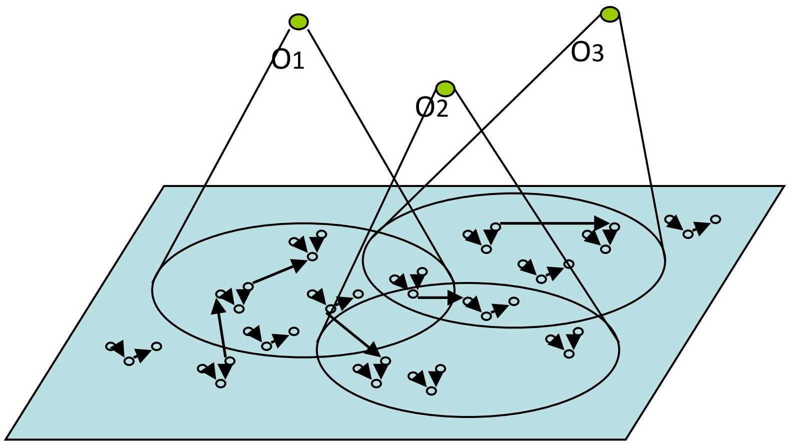

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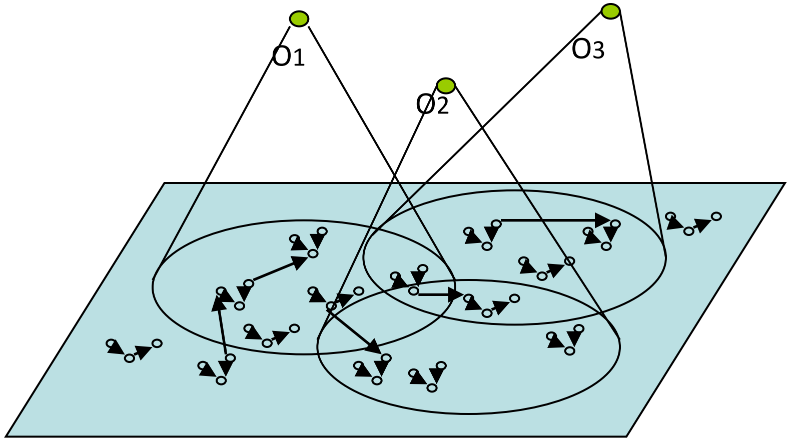
Technical Approach

Problem: Dynamic Data

Constantly changing data from many sources leads to fragmented, inefficient search methods.

Approach: Characterize and Investigate

1. Observe actual composition and structure, and define nature of changes.
2. Investigate areas of theory that can accommodate observations.
3. Investigate initial feasibility.



Data Environment

Multi-Source Intelligence (Multi-INT)

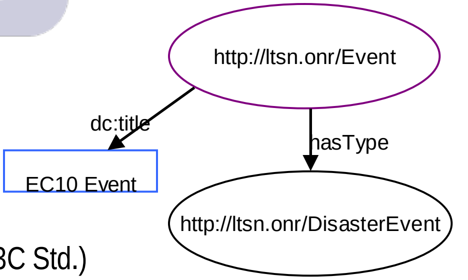
- Images
- Video
- Comms
- Geo
- Human
- RF
- ...

Processing

- E/R Extraction
- Sentiment
- Tracking

Common Access Storage

- Federated Storage in RDF* Format



* RDF: Resource Description Format (W3C Std.)
http://www.w3.org/TR/rdf-primer/

The Event Continuum

Complex Event Processing

Static Networks
- Social Networks
- Concurrent
- Simple relations
- Simple dependencies

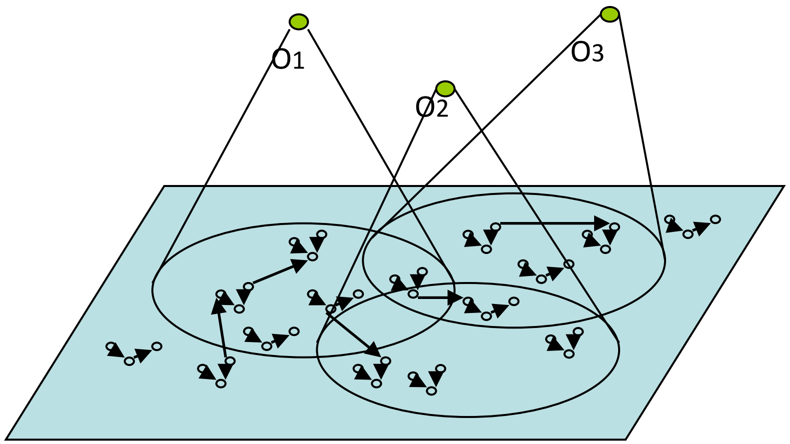
Dynamic Networks
- Temporal persistence
- Complex relations
- Complex dependencies
- Evolution over time

Event Sequences
- Sequence dominates
- Low persistence
- Independent events
- No concurrency

Three distinct regimes in the literature. Complex Event Processing in AIW event streams rarely has the characteristics of Static Networks.

Technical Approach

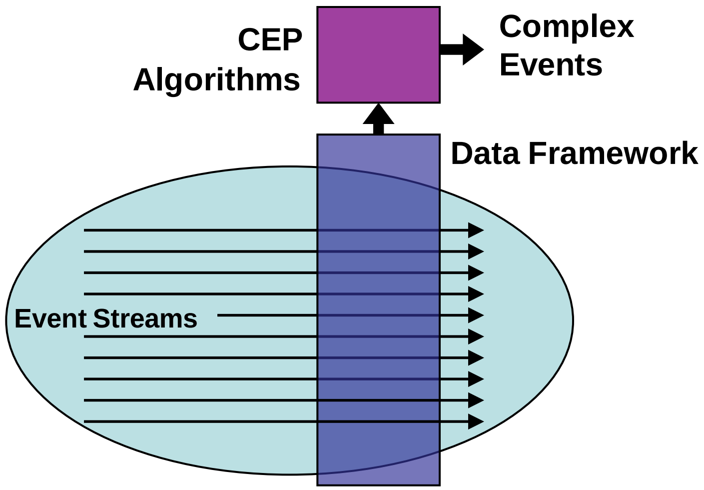
Characterization:
- Variable temporal persistence.
- Independent events.
- Complex dependences.
- Evolution.
- Sequential events.
- Concurrent events.



Investigate:
- Dynamic graph theory.

Initial feasibility:
- Algorithm prototype.

Prototype Implementation



A Framework and Algorithms to infer complex events from high-volume streams of events in near-real time.

Technical Approach

The approach involves the following steps:

1) Event Streams: Investigate structure and phenomenology of EIW events and event streams. Augment streams by adding context, time stamps, pedigree and graph structure.
2) Data Framework: Tag and encode the data using lexicons, schemas, and ontologies. Investigate dynamic graph theory towards scalable graph update and search.
3) CEP Algorithms: Develop and implement new dynamic graph algorithms for approximate graph pattern search. Evaluate algorithms to identify relevant patterns, activities, and events.
4) MOP Evaluation: establish means to measure and improve performance.

Simplified Search Algorithm

Graph Pattern Match

Input: Pattern P=(Vp,Ep), Data Graph G=(V,E), and Ontology O

Initial step: compute all-pairs-shortest path matrix M.

A. Find descendent nodes, D_{Vp}=desc(Vp), in ontology of each pattern graph node.

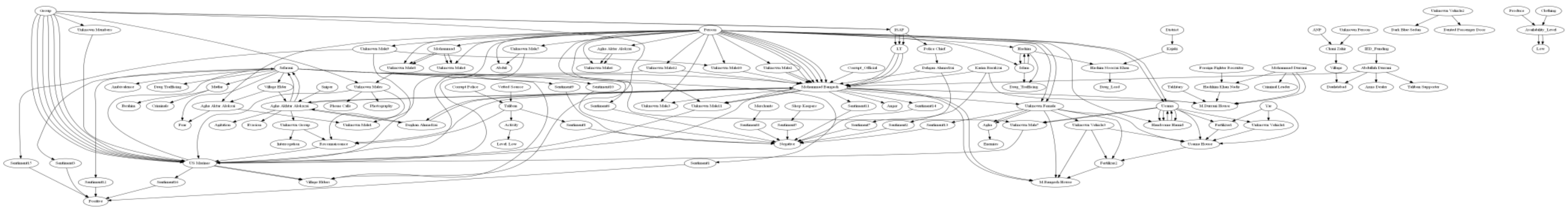
B. Compute potential matching set in G for each node in D_{Vp}.

C. Traverse paths in the matching set, examining path length and edge type. Remove nodes that are not connected, do not meet path constraints, or do not have correct edge type.

Distance matrix is updated as graph changes using algorithms from Ramalingam, 1996.

IIMEF Exercise: Key Leader Engagement (KLE)

KLE IPB Data Graph



Draft Intelligence Information Reports

DIIR_1-01.txt	DIIR_1-03.txt
DIIR_1-04.txt	DIIR_1-05.txt
DIIR_1-06.txt	DIIR_1-08.txt
DIIR_2-01.txt	DIIR_2-02.txt
DIIR_2-05.txt	DIIR_3-01.txt
DIIR_3-03.txt	DIIR_3-04.txt
DIIR_4-01.txt	DIIR_4-03.txt
DIIR_4-05.txt	DIIR_4-08.txt
DIIR_4-10.txt	DIIR_4-14.txt
DIIR_4-17.txt	

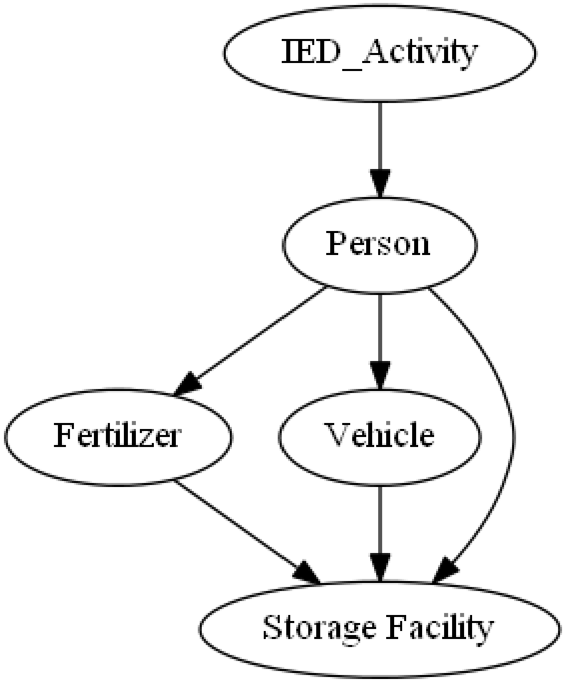
TACREPS

TACREP_1-02.txt	TACREP_2-03.txt
TACREP_2-04.txt	TACREP_2-06.txt
TACREP_3-02.txt	TACREP_4-02.txt
TACREP_4-04.txt	TACREP_4-06.txt
TACREP_4-09.txt	TACREP_4-11.txt
TACREP_4-12.txt	TACREP_4-13.txt
TACREP_4-16.txt	TACREP_4-18.txt
TACREP_4-19.txt	TACREP_4-21.txt

Dynamic Data Graph is built incrementally, as information becomes available.
Threat patterns can be detected at any time.

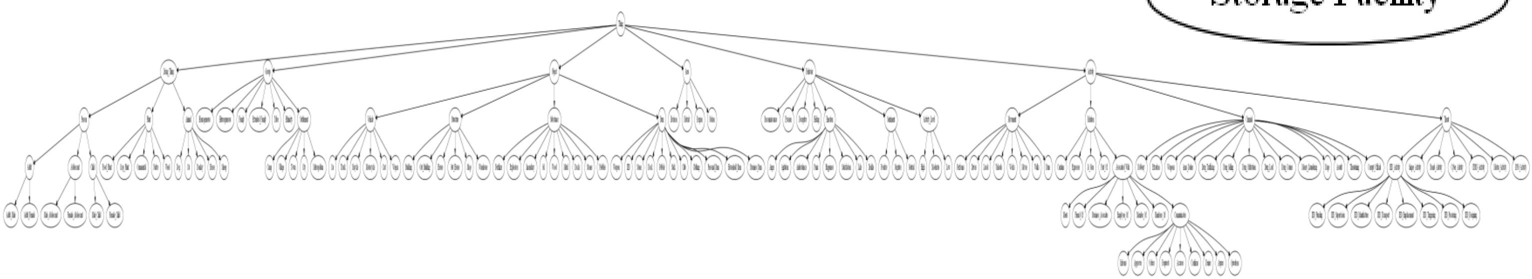
IPB: Intelligence Preparation for the Battlefield.

Threat Pattern Graph



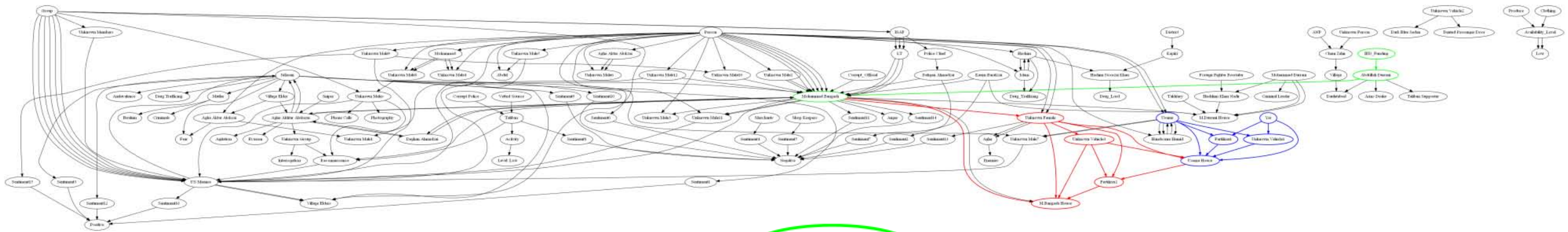
Watch for a Person with a previous involvement in IED Activity, and access to Fertilizer, a Vehicle, and a Storage Facility.

Given some hierarchy of objects and activities:



Watch the data as the graph changes and warn of any matching pattern.

Threat Warning Graph



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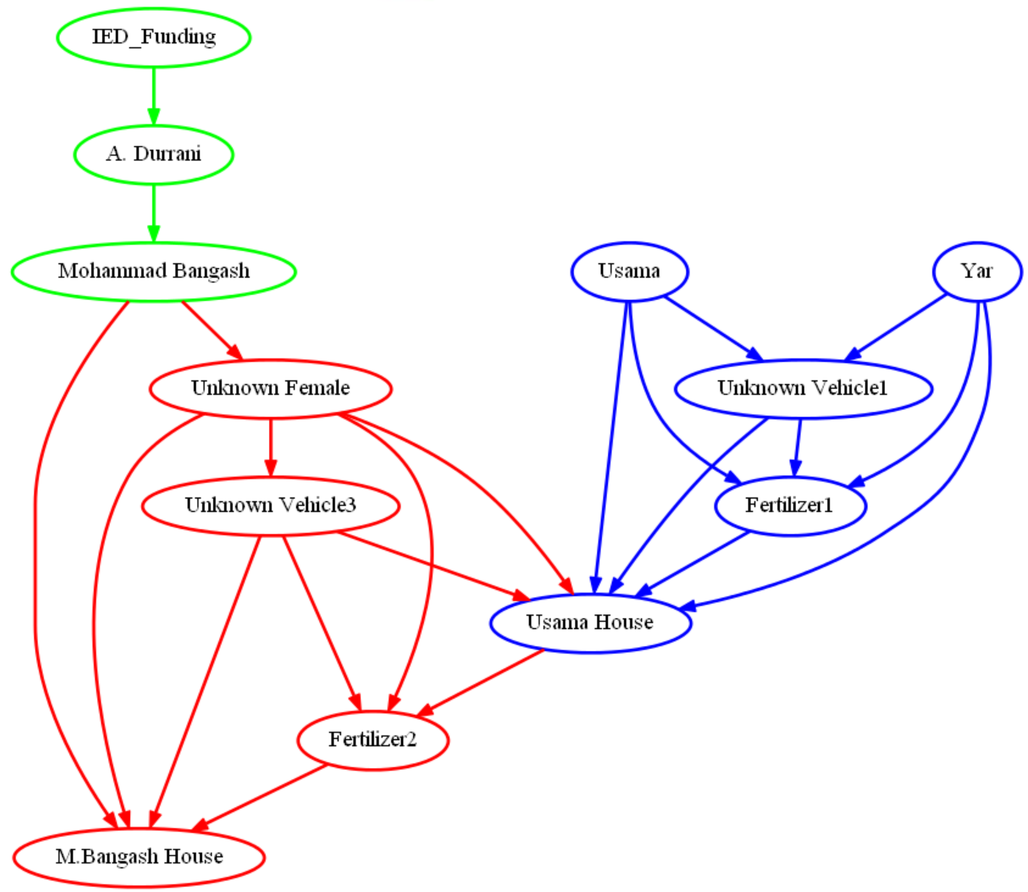
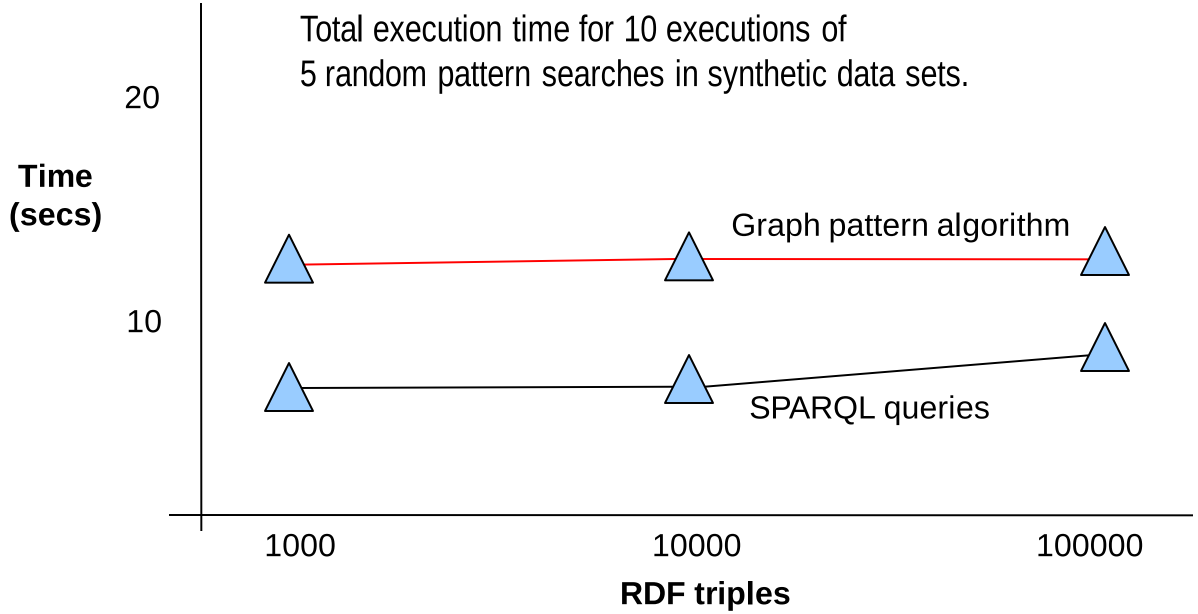


Initial Performance Comparisons



Graph Pattern algorithm prototype:
- 680 line implementation in Python
- Uses networkx graph library.
- Uses rdflib RDF library.

SPARQL query prototype:
- 200 line implementation in Python
- Uses rdflib RDF library.
- Uses rdflib SPARQL library.

Execution environment: Dell Precision T1500, Core i7 processor, 8GB RAM, Windows 7 OS, 1TB HD.

Results

- Completed initial studies of EIW data streams and content.
- Completed initial prototype of graph pattern search algorithms.
- Completed initial performance comparisons with std. search algorithms *(Naïve implementation was no worse than current standard algs, with improved capabilities)*.
- Developed graph encoding framework, including activity and event hierarchy.
- Developed preliminary methods of performance assessment for activity discovery.
- Implemented prototype incremental graph.

Issues

Data issues:

- Access to suitable data with documentation.
- Relatively small data set sizes.
- Time constraints for processing and encoding data.

Future Work

- Mature graph encoding work for wider application and greater robustness.
- Automate conditioning of data to facilitate larger-scale testing.
- Participate in user experiments, when/where possible.
- Investigate additional application areas with larger data sets.