Dynamic Networks: Rapid Assessment of Changing Scenarios

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Outline

• Challenge

• Properties of Dynamic Networks and Data

• Approach

• Sample Scenario

• Concluding Remarks
Challenge

• Application of network science technologies to aid analysis in real-world, highly dynamic environments
  – Large amounts of kinetic and non-kinetic data
  – Data is relational and rich in attributes (e.g., providence, time-of-occurrence)
  – Disparate sources producing uncertain and potentially conflicting information
Dynamic Networks

- The networks of concern are “Meta-Networks”
  - Multi modal: Different types of nodes
  - Multi link: Different types of relations
  - Multi level: Networks with multiple levels of aggregation (e.g., individual, group, organization)
Properties of Dynamic and Uncertain Data

- One or more sources with characteristics such as reliability and pedigree
- Delays in positive identification of unknown actors
- Entities and relationships that appear, disappear, and evolve over time as new information is processed

Dynamic networks can assist in detecting uncertain/missing data and provide actionable information for new collection activities
Properties of Standard Networks

- Show a single, static snapshot of a network
- Assume all data is complete and perfectly reliable
- Do not provide efficient means to represent multimodal, dynamic and uncertain data
Approach

• The capture and maintenance of network dynamics require the following extensions to standard Network Representation Languages

  – **Enhanced Edge Representation (EER)**
    - Attributes pertaining to strength, direction, reliability, existence, and change

  – **Enhanced Node Representation (ENR)**
    - Information regarding a node’s existence and state

  – **Enhanced Meta-Data Representation (EMR)**
    - Source, pedigree, temporal, and spatial report information
Enhanced Edge Representation

- Attributes pertaining to strength, direction, reliability, existence, and change

<reliability, type, time t>
<reliability, type, time t-1>
<reliability, type, time t>

Facilitates the specification of multiple relationship types each with metadata supporting temporal, spatial, and confidence values.
Enhanced Node Representation

- Information regarding a node’s existence and state

<attribute i, value x, confidence c, time t>
<attribute i, value x, confidence c, time t-1>
<attribute j, value x, confidence c, time t>
<attribute j, value x, confidence c, time t-1>

Facilitates the specification of state values for a node with supporting metadata such as confidence, temporal and spatial values
Enhanced Metadata Representation

- **Source, pedigree, temporal and spatial report information**

Facilitates confidence estimation and re-estimation pending information concerning a source.
Network Representation Language Score Card

• Developed a score card comparing newly developed and existing NRLs

• Limitations of Existing NRLs
  – Attempt to represent network dynamics and uncertainty as metadata
  – Lack in expressivity to capture and maintain EER, ENR and EMR
Core Network Modeling Language (CoreNetML)

- Extends CMU’s DyNetML
  - Provides geospatial and temporal tagging
  - Encodes multiple, sometimes conflicting values along with source and pedigree
  - Facilitates the specification of multiple relationships between any to nodes

CoreNetML is a hybrid of EER, ENR and EMR
Dynamic Impact Analysis

Dynamic NRLs enable dynamic analysis by static tools

- Core HumAn Network System (CHANS) ingests and manages dynamic human network data
- ORA and construct execute impact analyses on meta-networks
Scenario: ‘98 Tanzania Bombing

- Demonstrate changes in results of impact analysis from using dynamic networks
  - Use a human network from data available from open sources before the 1998 Tanzania US Embassy bombing
  - Execute ORA’s impact analysis when changes in the network are observed
  - Observe a change in the network’s key actors based on communication reports
Tanzania Terror Network 1996-1998

- In 1996, Khalfan Mohamed is the emergent leader and Abdullah Ahmed Abdullah is the boundary spanner
• In 1997, communication with Wadih el Hage is detected and impact analyses show him as the emergent leader
Connection between Mohamad Owhali and Bin Laden place Khalfan Mohamed as the emergent leader once again
Concluding Remarks

- Dynamic network representation languages must be expressive enough to persist conflicting reports, maintain geospatial and temporal information along with source and pedigree metadata.

- Persistence and maintenance of dynamic human networks enables increased situational awareness.
References

Questions