Estimating the near-term changes of an organization with simulation

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Introduction

• Interesting ‘what-if’ scenarios
  • What if some employees in a company resign,
    • Can the company perform at the same level?
  • What if some officers in a unit are not operable,
    • Can the unit be as responsive as usual?
  • What if some terrorists in a terrorist network are captured,
    • Can the network perform operations successfully?

• Also,
  • What would be the worst/best scenarios?
  • Are there any ways to create the scenarios systematically?
Background and related works (1)

- Interesting experiments with people
  - Virtual software company (Weber et al, 2004)
    - Varied company structure, from centralized/hierarchical to decentralized/egalitarian
    - Centralized/hierarchical firms -> rapid development
    - Decentralized/egalitarian firms -> easy assimilation of new entrants
  - Decision makers of organizations (Jin and Levis, 1990)
    - A parallel structure versus a hierarchical structure
    - Individual difference has more influence on performance in the parallel organization
    - Interactions in the hierarchical organization restricted the choices of the decision makers.
  - Unit of Action experiments (Graham, 2005)
    - Role-playing with an experimental command and control structure
    - Small cell structures and inter-cell connections
    - Identified social distance, physical distance and background similarity as important factors of shared situation awareness

Background and related works (2)

- Interesting experiments with multi-agent simulations
  - CORP (Carley and Lin, 1995)
    - Examined organizational structures and their performance under various test conditions (operating in optimal conditions, operating under internal/external stresses, etc)
  - Construct (Schreiber and Carley, 2004)
    - A validation study on Construct
      - Compared the generated probability interaction matrix to the communication frequency from surveys
      - An empirically validated what-if analysis
        - Did what-if analyses with the cases showing high correlation between the simulation result and the survey result
        - Plot the expected performance changes over time
  - Virtual Design Team (Kunz, Levitt and Jin, 1998)
    - Develop computational tools to analyze decision making and communication behavior to support organizational reengineering
    - Output includes the predicted time to complete a project, the total effort to do the project, a measure of process quality, etc.
    - Reducing time to market -> previously sequential activities
Common aspects of previous papers

• Some important factors considered in the papers
  • Organizational structure
  • Distribution of resource/knowledge
  • Dependencies among tasks, resource and knowledge
  • Multi-agent simulation/experiment

Dynamic Network Analysis and Computational Modeling

• Proposed ‘Near-Term Analysis’ use Dynamic Network Analysis approach (Carley, 2003)
  • Input requires information about agent, knowledge, resource, task, and etc.
    -> Meta-Matrix
  • Generated networks have probabilistic ties.
    -> Treating ties as probabilistic
• Bridging ORA and Construct
  -> Combining social networks and multi-agent system
Near Term Analysis

- What if we isolate a few agents in a network
  - How fast can knowledge be diffused?
  - How accurately can tasks be performed?
  - How might the network structure be affected?

- Near Term Analysis assumes the what-if scenario (isolation of agents, resource, or knowledge) and performs a simulation with the scenario.

Input data – Network info.

- Need two datasets
  - network information and isolation scenarios

- Meta-Matrix
  - Knowledge, resource and task nodes are required for Near-Term analysis.

<table>
<thead>
<tr>
<th>People / Agents</th>
<th>Knowledge / Resources</th>
<th>Tasks / Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>Social Network</td>
<td>Knowledge Network</td>
<td>Assignment Network</td>
</tr>
<tr>
<td>Knowledge / Resources</td>
<td>Information Network / Substitutes</td>
<td>Needs Network</td>
</tr>
<tr>
<td>Tasks / Events</td>
<td>Precedence Ordering</td>
<td></td>
</tr>
</tbody>
</table>
Input data - Isolation strategy (1)

- To make a what-if scenario, we need a set of agents for exploring isolation strategies
  - Input from ORA
    - Intelligence Report identifies several key nodes (agent, knowledge, resource, organization)
    - Isolate each node from Intelligence Report that is identified by any measures one at a time
    - Isolate all the top nodes for a measure as identified in Intelligence Report and repeat for each measure
  - Input from User
    - Isolate nodes as a user specifies

Input data - Isolation strategy (2)

- Intelligence report includes the lists of nodes identified by various measures.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Implication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cognitive demand</td>
<td>Measures the total amount of effort expended by each agent to do its tasks.</td>
</tr>
<tr>
<td>Total degree centrality</td>
<td>The Total Degree Centrality of a node is the normalized sum of its row and column degrees.</td>
</tr>
<tr>
<td>clique count</td>
<td>The number of distinct cliques to which each node belongs.</td>
</tr>
<tr>
<td>eigenvector centrality</td>
<td>Calculates the principal eigenvector of the network. A node is central to the extent that its neighbors are central.</td>
</tr>
<tr>
<td>betweenness centrality</td>
<td>The Betweenness Centrality of node ( v ) in a network is defined as: across all node pairs that have a shortest path containing ( v ), the percentage that pass through ( v ).</td>
</tr>
<tr>
<td>high betweenness and low degree</td>
<td>The ratio of betweenness to degree centrality; higher scores mean that a node is a potential boundary spanner.</td>
</tr>
<tr>
<td>shared situation awareness</td>
<td>A measure of situation awareness between agents.</td>
</tr>
</tbody>
</table>
Other input parameters

- Length of simulation time period
- Number of replication

**Note:** The Near-Term Analysis runs using agents interactions based on relative similarity of the knowledge network by default
  - The ability to change these parameters will be available in upcoming versions.

Near Term Analysis Result

- The changes of performance measures
  - Knowledge Diffusion
  - Task accuracy
- The changes of network itself
  - An evolved meta-matrix

- These results shows the near term impact of isolating one agent in organization.
Near Term Analysis Result – meta-matrix evolution

• Evolved meta-matrixes
  • Three factors
    • Agent-to-Agent friendship matrix based on relative similarity (range: [0..1])
    • Agent-to-Agent advise matrix based on relative expertise (range: [0..1])
    • Agent-to-Agent interaction matrix based on interaction during simulation (range: integer)
  -> Generate a network with the weighted sum of the above matrixes

A sample dataset

• Embassy bombing case
  • Use embassy.xml meta-matrix
  • Use Its intelligence report from ORA
  • 3 replications
  • 52 simulated time-point
  • Isolate nodes at time-point 20

INTELLIGENCE REPORT FOR [EMBASSY]

KEY ACTORS

Emergent Leader (cognitive demand)
Measures the total amount of effort expended by each agent to do its tasks.

1  0.3793  Fazul Abdullah Mohammed
2  0.3411  Khalfan Khamis Mohamed
3  0.3007  Mohammed Rashed Daoud al-Owhali
4  0.2807  Jihad Mohammed Ali
5  0.2702  Mohammed Sadiq Odeh
6  0.2450  Abdullah Ahmed Abdullah
7  0.1925  Mohammed Salim
8  0.1842  Ahmed the German
9  0.1825  Wadih al Hage

……………………………….
Results from the sample dataset

- Results from Embassy bombing case with isolation strategies set by intelligence report.
- Jump at the isolation timing
- Changes over time
- Some strategies optimized the target organization, and others degraded the organization’s performance.

Near-Term Analysis for pseudo parallelism

- The workflow of Near-Term Analysis in MAUI computing center
- Can launch multiple replications at the same time
Questions

Reference