One and Two Mode Metrics, Folding

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Agenda

• Concepts
  – Types of networks
  – Types of metrics
• Network Metrics in ORA
  – Overview
  – Common one/two mode metrics
• Experiments
  – Color nodes by network metrics
  – Generate one/two mode network metrics from ORA report
  – Hiding Network type Information from ORA Metrics
• Folding Networks
Concepts-Types of Networks

• One mode networks
  – Networks consist of only one node class
  – E.g. Social Networks (Agent by Agent), Transportation networks (Location by Location)

• Two mode networks
  – Networks consist of two node classes
  – E.g. Travel Networks (Agent by Location), Expert Networks (Agent by Knowledge)

Concepts-Types of Networks

• Binary/Weighted Networks
  – Binary Networks only contain 0/1 information on links
  – Weighted Networks contain additional information of links. E.g. cost of a path, the amount of knowledge one have.

• Self-loop/No Self-loop Networks
  – Self-loop Networks contains links that point to the source.
  – E.g. social interaction networks are free from self loops.
  – E.g. company interaction networks may have self loops.

• Symmetric/asymmetric Networks
  – Symmetric networks assume both directions of a link contain the same information.
  – E.g. Facebook friend network is symmetric. Email network is not.
Concepts - Types of Metrics

- Network Metrics
  - Measure the networks based on a specific standard
  - One mode metrics, e.g. Centralizations
  - Two mode metrics, e.g. Knowledge Exclusiveness

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Network Metrics in ORA-Overview

- 170 + metrics in ORA
  - Metrics are grouped. Similar metrics have the same "last name". E.g. centrality
  - In every group, each metric has a unique “first name”. E.g. betweenness, closeness.

- Input of metrics
  - Metrics may have network level version, node level version or both versions in ORA.

- Computation time
  - Labeled with Fast/Medium/Slow

- Based on whether the metrics use weighted information
  - Some metrics are designed to utilize weighted information while others are not.
  - Metrics do not use weighted information will treat weighted networks as binary ones.

- Normalizations of metrics
  - Normalizations maps the metrics into a 0 to 1 space
  - All node level metrics have normalized versions in ORA
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Common One/Two Mode Metrics

One Mode Metrics
Common One Mode Metrics

1. Degree Centrality
   - Measures the number of connections of a node in the network
   \[ C_D(u) = \begin{cases} \frac{1}{N} \sum_{v=1}^{N} w_{v,u} & \text{allow self-loops} \\ \frac{1}{N-1} \sum_{v=1,v\neq u}^{N} w_{v,u} & \text{ignore self-loops} \end{cases} \]
   - Implementations in ORA:
     - Centrality, In degree. Counts only in-links.
     - Centrality, Out degree. Counts only out-links
     - Centrality, Total degree. Counts both in-links and out-links
   - Input:
     - Uses node level information
     - Utilizes weighted information

2. Betweenness Centrality
   - counts the number of shortest paths through a specific node
   \[ C_B(k) = \begin{cases} \frac{1}{|V|} \sum_{v=1}^{|V|} \frac{\sigma_{uv}(k)}{\sigma_{uv}} & \text{symmetric networks} \\ \frac{1}{|V|-1} \sum_{v=1,v\neq u}^{|V|} \frac{\sigma_{uv}(k)}{\sigma_{uv}} & \text{asymmetric networks} \end{cases} \]
   - Implementations in ORA
     - Centrality, Betweenness
   - Input:
     - Uses node level information
     - Utilizes weighted information
Common One Mode Metrics

3. Closeness Centrality
- Calculates the inverse of shortest path from one node to all other nodes

\[ C_c(k) = \frac{1}{\sum_{u=1}^{\mid V \mid} d_{k,u}} \]

- Implementations in ORA
  - Centrality, Closeness. Utilizes only out-links.
  - Centrality, Inverse Closeness. The inverse of closeness centrality.
  - Centrality, In-Closeness. Utilizes only in-links

- Input:
  - Uses node level information
  - Utilizes weighted information

4. Eigenvector Centrality
- Measures influence of nodes
  - Nodes get high scores if they are connected to other high score nodes

- Implementations in ORA
  - Centrality, Eigenvector

- Input:
  - Uses node level information
  - Utilizes weighted information
Common One Mode Metrics

5. Clustering Coefficients
   - Measure the proportion of network cliques one node participated
   \[ C_c = \frac{\sum_{u=1}^{n} C'_c(u^*) - C'_c(u)}{\max(\sum_{u=1}^{n} C'_c(u^*) - C'_c(u))} \]

   - Implementations in ORA:
     - Density, Clustering Coefficients

   - Inputs
     - Uses node level information
     - Do not utilizes weighted information

6. Network Centrality
   - Measure the network level centrality
   \[ C_B = \frac{\sum_{u=1}^{n} C_B(u^*) - C_B(u)}{\max(\sum_{u=1}^{n} C_B(u^*) - C_B(u))} \]
   \[ C_O = \frac{\sum_{u=1}^{n} C'_O(u^*) - C'_O(u)}{\max(\sum_{u=1}^{n} C'_O(u^*) - C'_O(u))} \]
   \[ C_C = \frac{\sum_{u=1}^{n} C'_C(u^*) - C'_C(u)}{\max(\sum_{u=1}^{n} C'_C(u^*) - C'_C(u))} \]

   - Implementations in ORA:
     - Network centrality, In degree
     - Network centrality, Out degree
     - Network centrality, Total degree
     - Network centrality, Betweenness
     - Network centrality, Closeness
Common One Mode Metrics

• Input:
  – Uses network level information
  – Utilizes weighted information

Reference for Implementation Details

### Common One Mode Metrics

Some of the One Mode Network Metrics in ORA

<table>
<thead>
<tr>
<th>Measure Title</th>
<th>Measure Title</th>
<th>Measure Title</th>
<th>Measure Title</th>
<th>Measure Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potential</td>
<td>Boundary Spanner</td>
<td>Total Degree Centrality</td>
<td>Local Efficiency</td>
<td>Weak Component Members</td>
</tr>
<tr>
<td>Betweenness</td>
<td>Centrality</td>
<td>Bonacich Power</td>
<td>Centrality Lateral Link Count</td>
<td>Burt Constraint</td>
</tr>
<tr>
<td>Betweenness</td>
<td>Centrality</td>
<td>Eigenvector Centrality</td>
<td>Pooled Link Count</td>
<td>Eigenvector Centralization</td>
</tr>
<tr>
<td>Authority</td>
<td>Centrality</td>
<td>Node Count</td>
<td>Reciprocal Link Count</td>
<td>In-Closeness Network Centralization</td>
</tr>
<tr>
<td>Closeness</td>
<td>Centrality</td>
<td>Classic SNA Density</td>
<td>Sequential Link Count</td>
<td>Total Degree Eigenvector Centralization</td>
</tr>
<tr>
<td>Hub</td>
<td>Centrality</td>
<td>Clustering Coefficient</td>
<td>Density Effective</td>
<td>Skip Link Count Component Centrality</td>
</tr>
<tr>
<td>In-Closeness</td>
<td>Centrality</td>
<td>Burt Network Size</td>
<td>Strong Component Count</td>
<td>Information Centrality Network Centralization</td>
</tr>
<tr>
<td>Inverse</td>
<td>Centrality</td>
<td>Global Efficiency</td>
<td>Weak Component Count</td>
<td>Betweenness Centrality</td>
</tr>
<tr>
<td>Closeness</td>
<td>Centrality</td>
<td>Inverse Closeness</td>
<td>Weak Component Count</td>
<td>Betweenness Centrality</td>
</tr>
</tbody>
</table>

### Common One/Two Mode Metrics

Two Mode Metrics
Common two mode metrics

- Two mode Networks
  - Use two initials of node class to denote the two mode networks
  - E.g. AK (Agent by Knowledge) network, AL (Agent by Location) network
  - Without lose of generality, we use AK as an example.

- Notations
  - $A_{ij}$ the adjacent matrix of AK networks
  - $A_{ij}$ the element of the adjacent matrix located in $i$th row and $j$th column
  - $|A|$ the number of agents in the networks
  - $|K|$ the number of knowledge in the networks

Common two mode metrics

- Categories of Two Mode Network Metrics:
  - Quantity
    - Metrics in this category count or average the entries of the adjacent matrix
  - Variance
    - Metrics in this category create network level indices that describe the distributions of connections in Networks
  - Correlation
    - Metrics in this category describe similarities/dissimilarities between all pair of agents
  - Specialization
    - Metrics in this category identify agents that have either exclusive or redundant connections to other node class entities.
Common two mode metrics

1. Load
   - A quantity category metric measures the average amount of resources (Knowledge) per agents
   \[
   L = \frac{\sum_{i=1}^{[A]} \sum_{j=1}^{[K]} A_i K_j}{|A|}
   \]
   - Implementations in ORA
     - Load, Knowledge
     - Load, Resource
   - Input
     - Network level information
     - Treat all networks as binary

2. Diversity
   - A variance category metric measures whether the Knowledge is equally distributed.
   \[
   w_j = \sum_{i=1}^{[A]} A_i K_j \\
   W = \sum_{j=1}^{[K]} w_j \\
   D = 1 - \sum_{j=1}^{[K]} \frac{w_j^2}{W^2}
   \]
   - Implementations in ORA
     - Diversity, Knowledge
     - Diversity, Resource
   - Input
     - Network level information
     - Treat all networks as binary
Common two mode metrics

3. Expertise
   - A correlation category metric measures the degree of dissimilarity between agents based on shared knowledge
     \[ E(\sim AK \cdot AK') \quad \text{with} \quad E(i, i) = 0 \quad E(i, :) = \frac{\sum E(i, :) - 1}{|A| - 1} \]

   - Implementations in ORA
     - Correlation, Expertise

   - Input:
     - Node level information
     - Treat all networks as binary

4. Redundancy
   - A specialization category metric measures whether there are different agents sharing the same knowledge
     \[ d_j = \max[0, \sum AK(:, j) - 1] \quad r = \frac{\sum_{j=1}^{n} d_j}{|K|} \]

   - Implementations in ORA
     - Redundancy, Knowledge
     - Redundancy, Resource

   - Input:
     - Network level information
     - Treat all networks as binary
Common two mode metrics

Some of the Two Mode Network Metrics in ORA

<table>
<thead>
<tr>
<th>Measure Title</th>
<th>Measure Title</th>
<th>Measure Title</th>
<th>Measure Title</th>
<th>Measure Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge Based</td>
<td>AccessIndex Similarity</td>
<td>Correlation Resource</td>
<td>Exclusivity Row Redundancy</td>
<td></td>
</tr>
<tr>
<td>Resource Based</td>
<td>AccessIndex Relative</td>
<td>CognitiveDistinctiveness Task Exclusivity Knowledge Redundancy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Social Technical</td>
<td>Congruence Knowledge Diversity</td>
<td>Relative CognitiveExpertise Access Redundancy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distinctiveness</td>
<td>correlation Resource Diversity Knowledge Load Resource Redundancy</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Expertise</td>
<td>correlation Complete Exclusivity Resource Load Assignment Redundancy</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resemblance</td>
<td>correlation Knowledge Exclusivity Column Redundancy Relative CognitiveResemblance</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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- Folding Networks
Generate A Simple Network

1. Create a new network
2. Choose "design a meta-network"
3. Hit "next"
1. Name whatever you want
2. Choose “Agent” and select 8 as size
3. Create an “Agent X Agent” network
4. Hit “Finish”

1. Click to expand your meta-network
2. Choose your Agent X Agent network
4. Hit Visualize Network
Generate A Simple Network

Use “Link Creator” to create a network that look like the picture.

Color Network By Metrics (One Mode)

Select “Node-Appear”-> “Node Color”->“Color Nodes by Attribute or Measure”
Total Degree Centrality

Betweenness Centrality
Closeness Centrality

Eigenvector Centrality
Color Network By Metrics (One Mode)

Clustering Coefficients

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Experiment 2a

Generate one mode network metrics from ORA report

Load Startup Network
Generate one mode metrics from ORA

1. Select meta network
2. Click generate reports

1. Use Custom report
2. Click Filter Data
Generate one mode metrics from ORA

1. Check only Agent
2. Click Measures

1. Select Run with specific measures
2. Click Select/Clear All
1. Type centrality
2. Select Centrality, Betweenness
3. Select Centrality, Closeeness
4. Select Centrality, Total-degree

1. Type Network centralization
2. Select Network Centralization, Betweenness
3. Select Network Centralization, Closeeness
4. Select Network Centralization, Total-degree
5. Click Next and save file to location
Generate one mode metrics from ORA

1. Click Next on this and following screens and select location to save

View Analysis node class agent
Generate one mode metrics from ORA

Agent-level Measures

<table>
<thead>
<tr>
<th>Metric</th>
<th>Mean</th>
<th>Median</th>
<th>Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Node-level 1</td>
<td>6.25</td>
<td>6.25</td>
<td>6.25</td>
</tr>
<tr>
<td>Node-level 2</td>
<td>4.75</td>
<td>4.75</td>
<td>4.75</td>
</tr>
<tr>
<td>Node-level 3</td>
<td>5.00</td>
<td>5.00</td>
<td>5.00</td>
</tr>
</tbody>
</table>

View Analysis for network Agent by Agent
Generate one mode metrics from ORA

Experiment 2b

Generate two mode network metrics from ORA report
Generate two mode metrics from ORA

1. Select meta network
2. Click generate reports

Load Startup Network
Generate two mode metrics from ORA

1. Use Custom report
2. Click Filter Data

1. Choose agent and knowledge
2. Choose only agent by knowledge
3. Select Measures
Generate two mode metrics from ORA

1. Select Run with specific measure
2. Click Select/Clear All

1. Type Load
2. Check Actual Load, Knowledge
3. Repeat for: Correlation, Expertise and Redundancy, Column.
4. Click Next and select location to save
Generate two mode metrics from ORA

CUSTOM REPORT

Input data: startup_company
Start time: Fri May 25 15:49:25 2020

Table of Contents

- Analysis for network agent x knowledge
- Analysis for nodeset agent

Produced by ORA, a joint product of the CASOS center at Carnegie Mellon University and Netanomics

Agent-level Measures

<table>
<thead>
<tr>
<th>Node Level</th>
<th>Agent</th>
<th>Segmentation</th>
<th>Node</th>
<th>Level</th>
<th>Node</th>
<th>Level</th>
<th>Node</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>startup_company</td>
<td></td>
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<tr>
<td>Company's Knowledge</td>
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<tr>
<td>Agent's Knowledge</td>
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</tr>
</tbody>
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View Analysis nodeset agent
Generate two mode metrics from ORA

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Hiding Network type Information from ORA Metrics

- When do you want to hide information from ORA metrics?
  - When you have a weighted network but want the ORA metrics to treat it as a binary network.
  - When you have a network with self-loop but want ORA to treat it as a no self-loop network.
  - When you have an asymmetric network but want ORA to treat it as a symmetric network.
- Why that matters?
  - Some measures have different implementations when network types are different.
  - ORA choose the versions of metrics by automatically detecting the network type.
Hiding Network type Information from ORA Metrics

1. Choose agent by agent network
2. Change Treat as symmetric to True

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- Folding Networks
Folding Networks (1/2)

• What is networks folding?
  – Convert a two mode network into a one model network by aggregating resources over a specific node class.
  – Folding an agent by knowledge network will yield an agent by agent network with each link represents the shared knowledge between them.
  – Mathematically, For a specific two mode network M, Folded Network F=M*M'

• Why do we fold networks?
  – To eliminate an additional dimension.
  – To calculate indirect relations.

Folding Networks (2/2)

<table>
<thead>
<tr>
<th>Person</th>
<th>Avg. Shared Knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Larry</td>
<td>3.50</td>
</tr>
<tr>
<td>Terry</td>
<td>3.00</td>
</tr>
<tr>
<td>Chuck</td>
<td>2.75</td>
</tr>
<tr>
<td>Andrea</td>
<td>2.00</td>
</tr>
<tr>
<td>Meindl</td>
<td>1.75</td>
</tr>
</tbody>
</table>
Folding Networks in ORA (1/4)

1. Right click Agent by Knowledge Network
2. Choose Fold Networks

Folding Networks in ORA (2/4)

1. Choose Rows (agent)
2. Check Use link weights
3. Click Fold
A new network with name ending with “shared knowledge” will appear.

Visualization shows the agent by agent network with links represent shared knowledge.
Questions?