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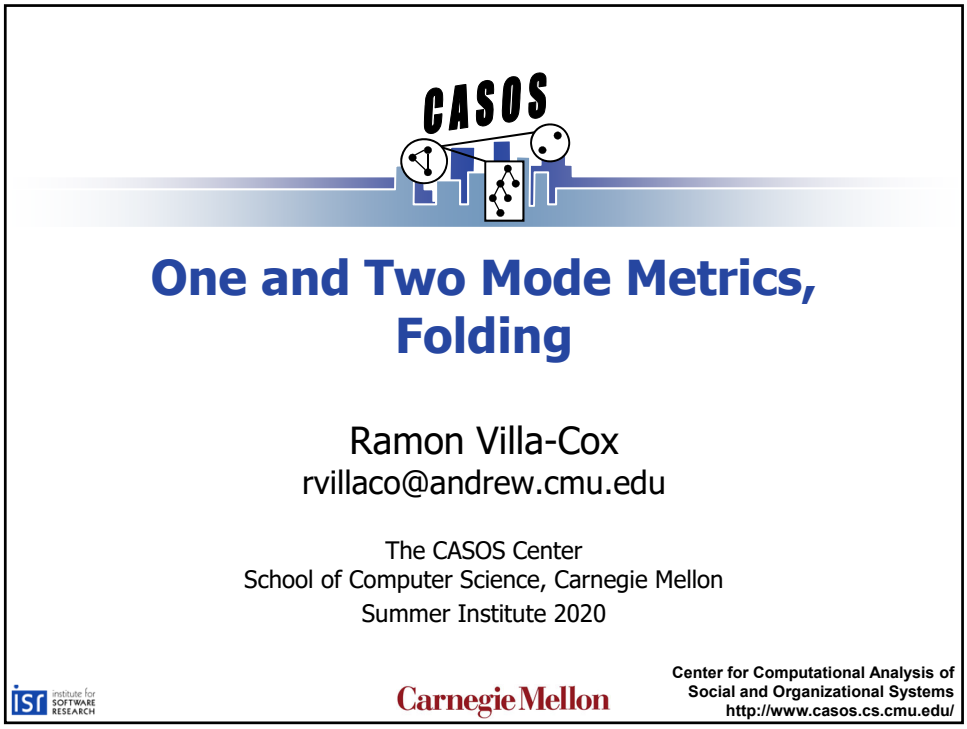
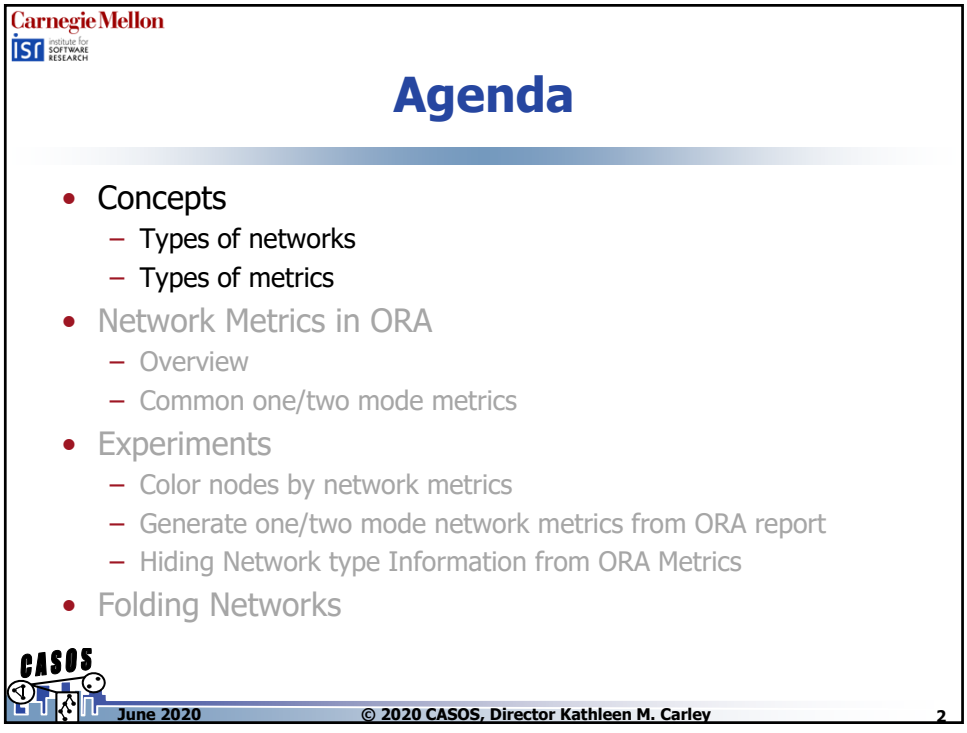


One and Two Mode Metrics, Folding

Ramon Villa-Cox
rvillaco@andrew.cmu.edu

The CASOS Center
School of Computer Science, Carnegie Mellon
Summer Institute 2020



Agenda

- Concepts
  - Types of networks
  - Types of metrics
- Network Metrics in ORA
  - Overview
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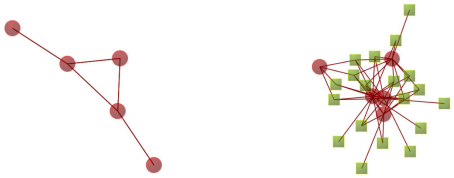
Concepts-Types of Networks

- 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)



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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.

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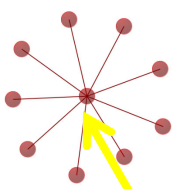
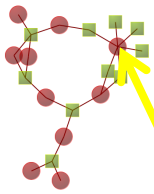
Concepts-Types of Metrics

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





High in Centrality

High in 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

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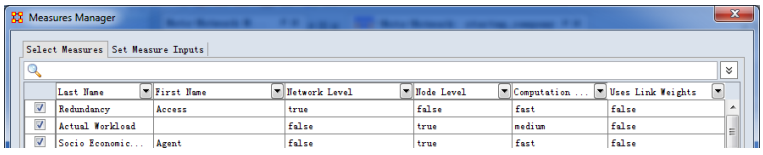
Network Metrics in ORA-Overview

- 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

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Common One Mode Metrics

- 1. Degree Centrality
  - Measures the number of connections of a node in the network

$$C_D(u) = \begin{cases} \sum_{v=1, v \geq u}^{|N|} w_{v,u} & \text{allow self-loops} \\ \sum_{v=1, v>u}^{|N|} w_{v,u} & \text{ignore self-loops} \end{cases}$$

- 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

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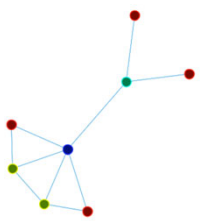
Common One Mode Metrics

- 2. Betweenness Centrality
  - counts the number of shortest paths through a specific node

$$C_B(k) = \begin{cases} \sum_{u=1}^{|V|} \sum_{v=u+1}^{|V|} \frac{g_{u,v}(k)}{g_{u,v}} & \text{symmetric networks} \\ \sum_{u=1}^{|V|} \sum_{v \neq u}^{|V|} \frac{g_{u,v}(k)}{g_{u,v}} & \text{asymmetric networks} \end{cases}$$

- Implementations in ORA
  - Centrality, Betweenness
- Input:
  - Uses node level information
  - Utilizes weighted information



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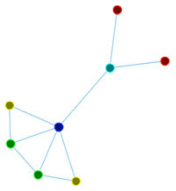
Common One Mode Metrics

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

$$C_C(k) = \frac{1}{\sum_{u=1}^{|V|} d_{k,u}}$$

- 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



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Common One Mode Metrics

- 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

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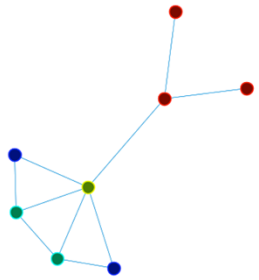
Common One Mode Metrics

- 5. Clustering Coefficients
  - Measure the proportion of network cliques one node participated

$$C_C = \frac{\sum_{u=1}^{u=|N|} C'_C(u^*) - C'_C(u)}{max\left(\sum_{u=1}^{u=|N|} C'_C(u^*) - C'_C(u)\right)}$$

- Implementations in ORA:
  - Density, Clustering Coefficients
- Inputs
  - Uses node level information
  - Do not utilizes weighted information



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Common One Mode Metrics

- 6. Network Centrality
  - Measure the network level centrality

$$C_D = \frac{\sum_{u=1}^{u=|N|} C_D(u^*) - C_D(u)}{max\left(\sum_{u=1}^{u=|N|} C_D(u^*) - C_D(u)\right)} \qquad C_B = \frac{\sum_{u=1}^{u=|N|} C_B(u^*) - C_B(u)}{max\left(\sum_{u=1}^{u=|N|} C_B(u^*) - C_B(u)\right)}$$

$$C_C = \frac{\sum_{u=1}^{u=|N|} C'_C(u^*) - C'_C(u)}{max\left(\sum_{u=1}^{u=|N|} C'_C(u^*) - C'_C(u)\right)}$$

- Implementations in ORA:
  - Network centrality, In degree
  - Network centrality, Out degree
  - Network centrality, Total degree
  - Network centrality, Betweenness
  - Network centrality, Closeness

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Common One Mode Metrics

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

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Reference for Implementation Details

- Wei Wei, Jürgen Pfeffer, Jeffrey Reminga, and Kathleen M Carley. Handling weighted, asymmetric, self-looped, and disconnected networks in ora. Technical Report CMU- ISR-11-113, Carnegie Mellon University, 2011.

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Common One Mode Metrics

Some of the One Mode Network Metrics in ORA

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

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Common One/Two Mode Metrics

Two Mode Metrics

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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
  - AK- the adjacent matrix of AK networks
  - A_iK_j - the element of the adjacent matrix located in ith row and jth column
  - |A|- the number of agents in the networks
  - |K|- the number of knowledge in the networks

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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.

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Common two mode metrics

- 1. Load
  - A quantity category metric measures the average amount of resources (Knowledge) per agents

$$L = \frac{\sum_{i=1}^{|A|} \sum_{j=1}^{|K|} A_i K_j}{|A|}$$

- Implantations in ORA
  - Load, Knowledge
  - Load, Resource
- Input
  - Network level information
  - Treat all networks as binary

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Common two mode metrics

- 2. Diversity
  - A variance category metric measures whether the Knowledge is equally distributed.

$$w_j = \sum_{i=1}^{|A|} A_i K_j \qquad W = \sum_{j=1}^{|K|} w_j \qquad D = 1 - \sum_{j=1}^{|K|} \frac{w_j^2}{W}$$

- Implementations in ORA
  - Diversity, Knowledge
  - Diversity, Resource
- Input
  - Network level information
  - Treat all networks as binary

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Common two mode metrics

- 3. Expertise
  - A correlation category metric measures the degree of dissimilarity between agents based on shared knowledge
  - $$\mathbf{E}(\sim AK \cdot AK') \qquad with\ \mathbf{E}(i,i) = 0 \qquad \mathbf{E}(i,:) = \frac{\mathbf{E}(i,:)}{\sum \mathbf{E}(i,:)}$$
    $$\mathbf{e}_i = \frac{\sum_{j=1, j\neq i}^{|A|} \mathbf{E}(i,j)}{|A| - 1}$$
- Implementations in ORA
  - Correlation, Expertise
- Input:
  - Node level information
  - Treat all networks as binary

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Common two mode metrics

- 4. Redundancy
  - A specialization category metric measures whether there are different agents sharing the same knowledge

$$d_j = \max[0, \sum AK(:,j) - 1] \qquad \mathbf{r} = \frac{\sum_{j=1}^{n} d_j}{|K|}$$

- Implementations in ORA
  - Redundancy, Knowledge
  - Redundancy, Resource
- Input:
  - Network level information
  - Treat all networks as binary

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Common two mode metrics

Some of the Two Mode Network Metrics in ORA

Measure Title		Measure Title		Measure Title		Measure Title	
Knowledge Based	AccessIndex	Similarity	Correlation	Resource	Exclusivity	Row	Redundancy
Resource Based	AccessIndex	Relative	CognitiveDistinctiveness	Task	Exclusivity	Knowledge	Redundancy
Social Technical	Congruence	Knowledge	Diversity	Relative	CognitiveExpertise	Access	Redundancy
Distinctiveness	correlation	Resource	Diversity	Knowledge	Load	Resource	Redundancy
Expertise	correlation	Complete	Exclusivity	Resource	Load	Assignment	Redundancy
Resemblance	correlation	Knowledge	Exclusivity	Column	Redundancy	Relative	CognitiveResemblance

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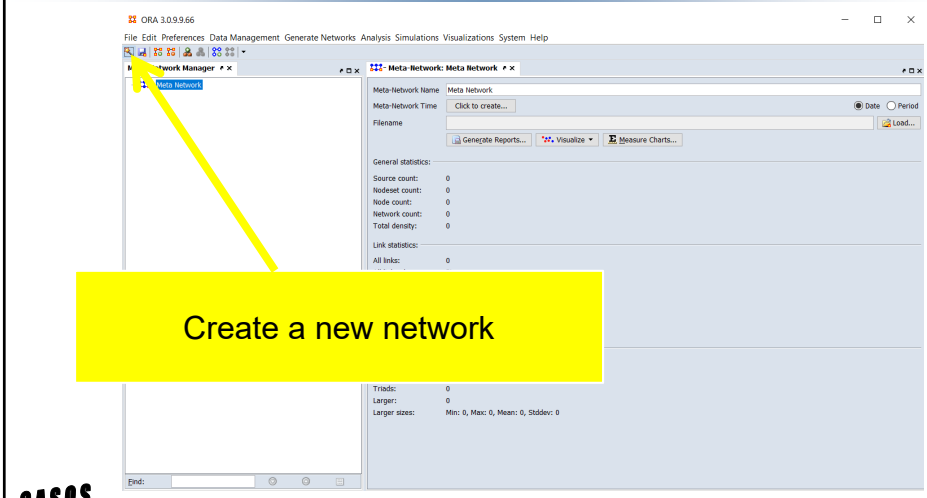
Generate A Simple Network



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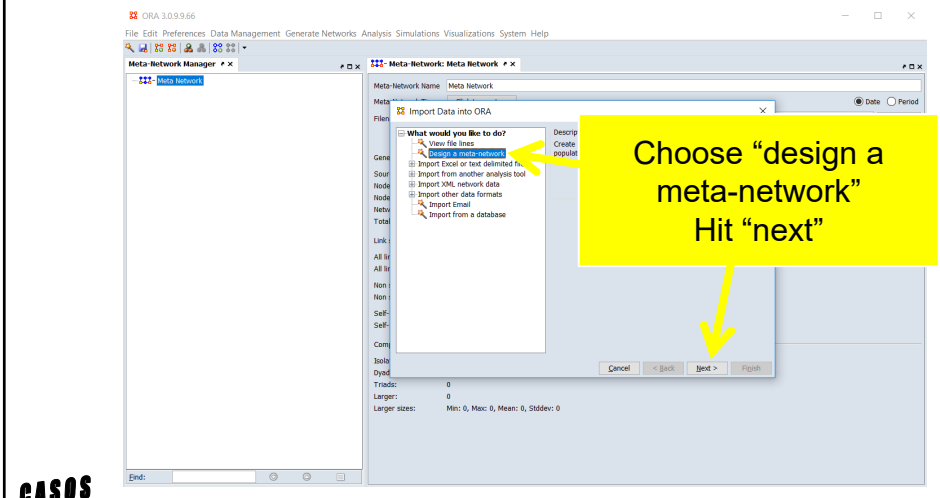

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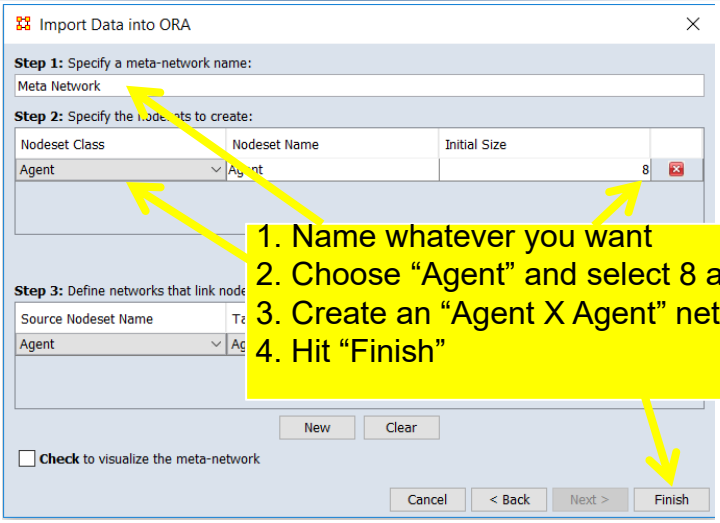

1. Name whatever you want
2. Choose “Agent” and select 8 as size
3. Create an “Agent X Agent” network
4. Hit “Finish”

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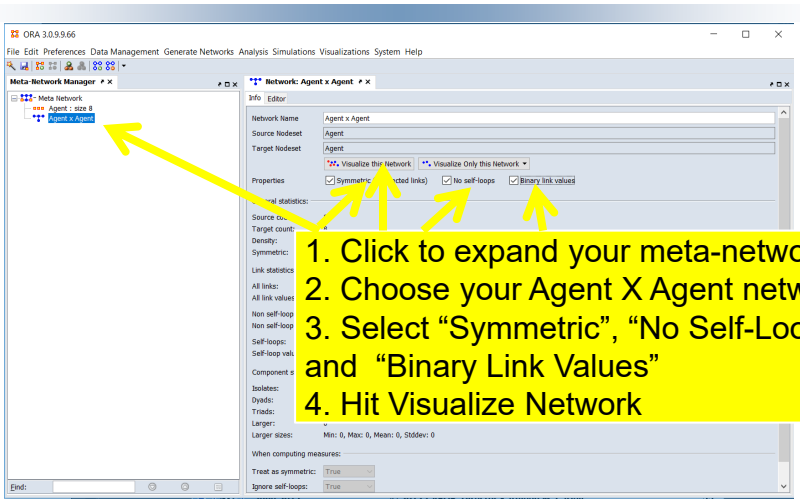
Generate A Simple Network



1. Click to expand your meta-network
2. Choose your Agent X Agent network
3. Select “Symmetric”, “No Self-Loops”, and “Binary Link Values”
4. Hit Visualize Network

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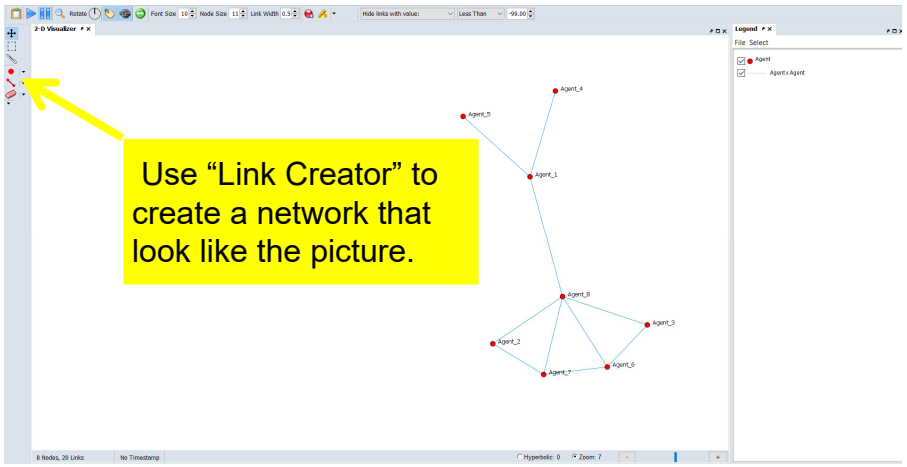
Generate A Simple Network



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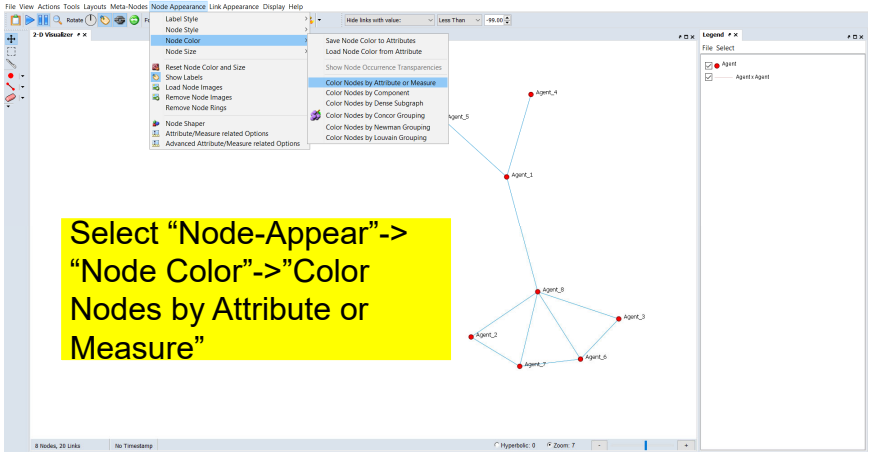
Color Network By Metrics (One Mode)



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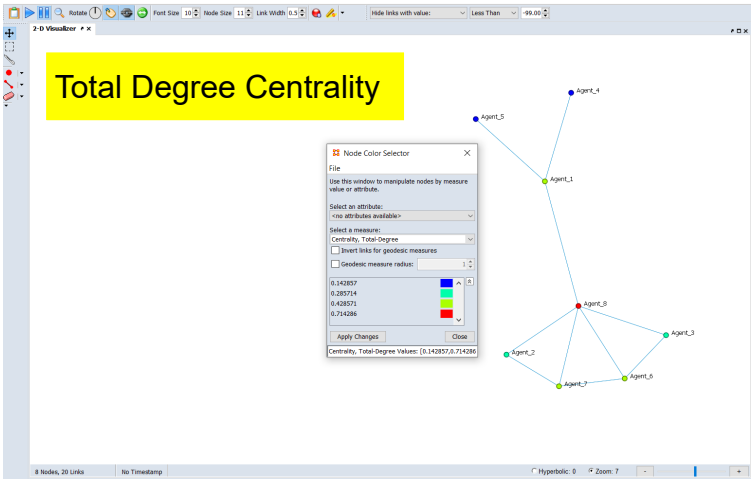
Color Network By Metrics (One Mode)

Total Degree Centrality



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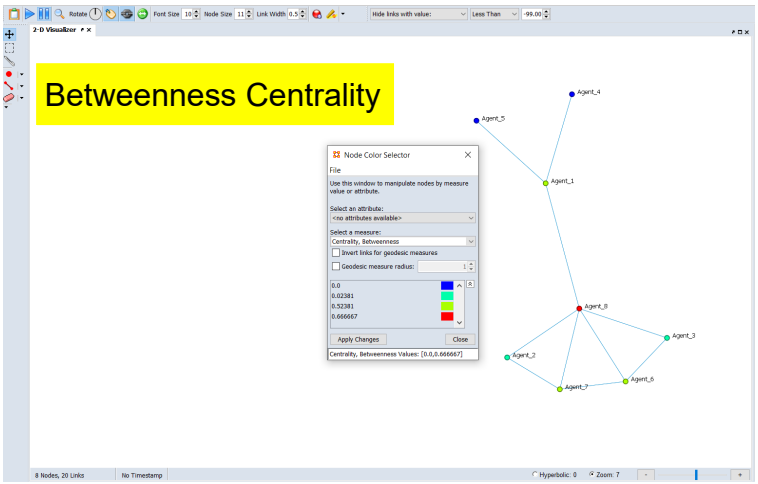
Color Network By Metrics (One Mode)

Betweenness Centrality



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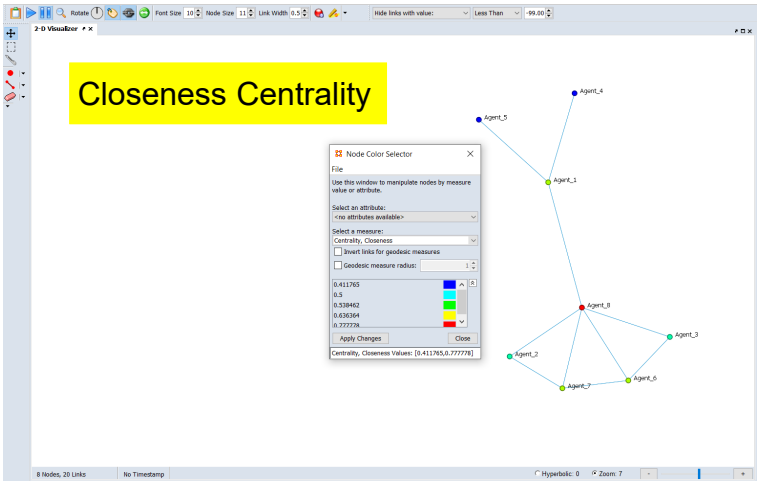

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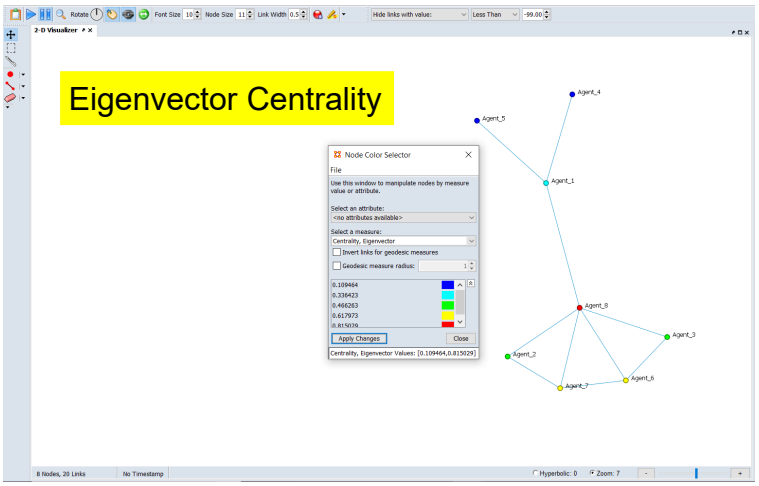

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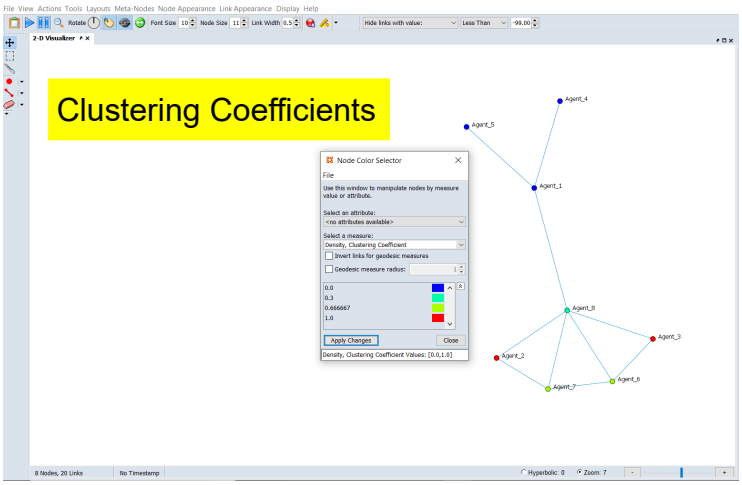

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Experiment 2a

Generate one mode network metrics from ORA report

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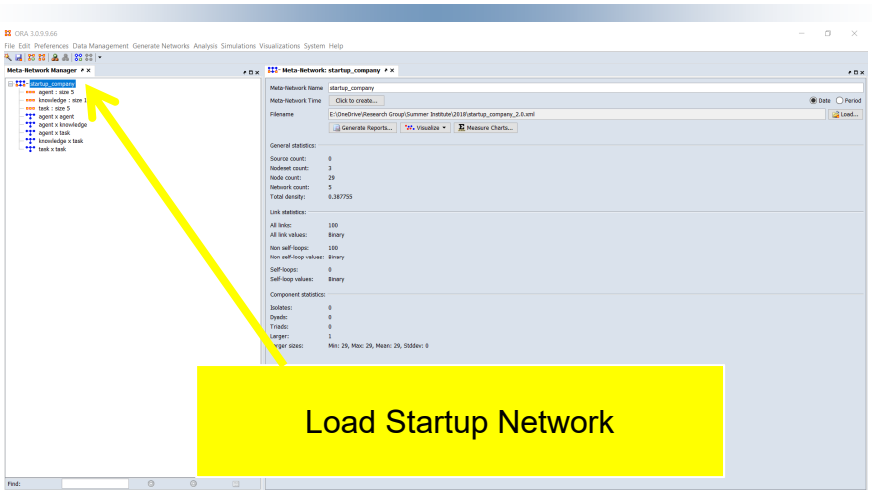
Generate one mode metrics from ORA



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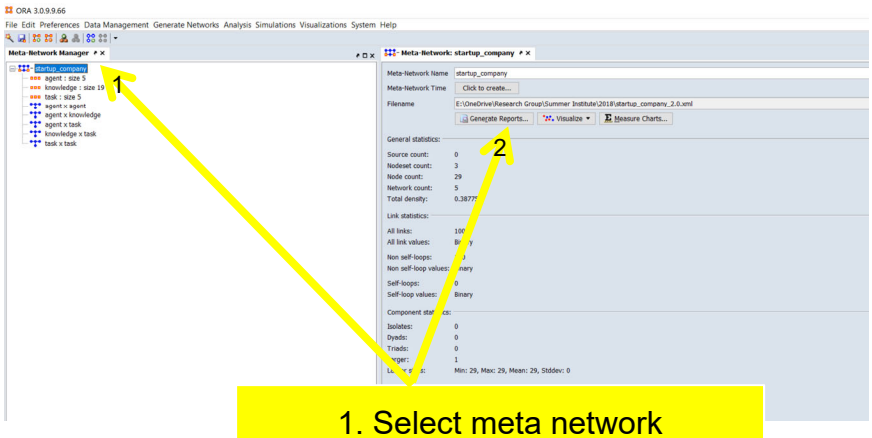
Generate one mode metrics from ORA



1. Select meta network
2. Click generate reports

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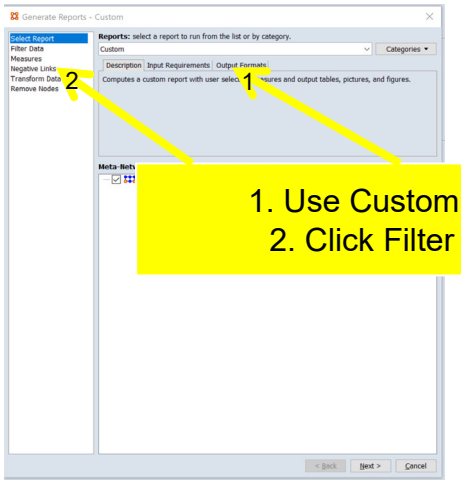
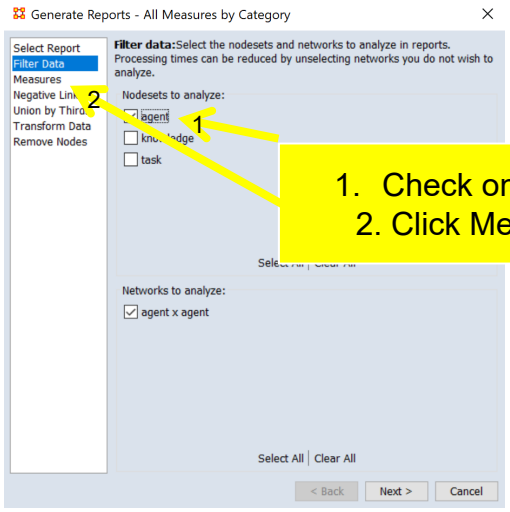
Generate one mode metrics from ORA



1. Use Custom report
2. Click Filter Data

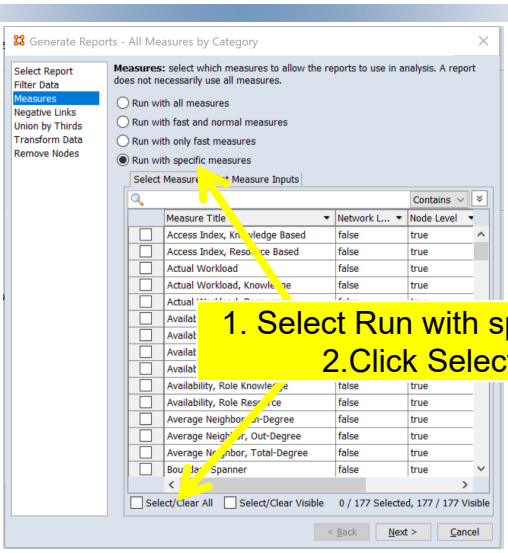
<Your Name>

Generate one mode metrics from ORA



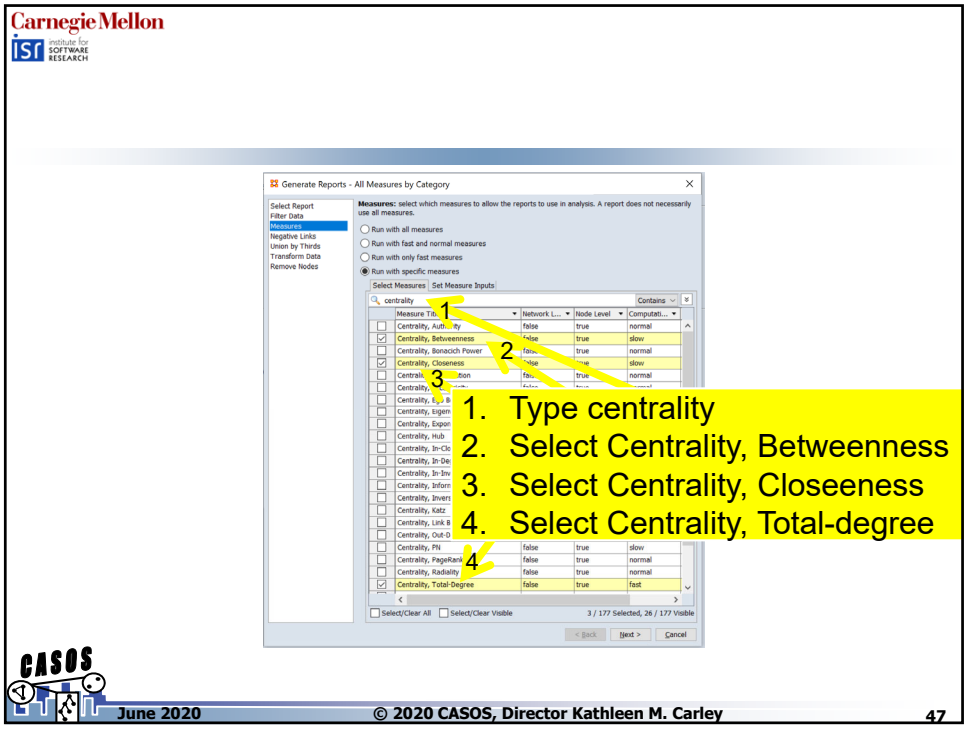
1. Check only Agent
2. Click Measures

Generate one mode metrics from ORA



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

<Your Name>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Generate Reports - All Measures by Category
Select Report
Filter Data
Measures
Negative Links
Union by Thirds
Transform Data
Remove Nodes
Measures: select which measures to allow the reports to use in analysis. A report does not necessarily use all measures.
Run with all measures
Run with fast and normal measures
Run with only fast measures
Run with specific measures
Select Measures
Set Measure Inputs
centrality
Contains
Measure Title
Network L...
Node Level
Computati...
Centrality, Betweenness
Centrality, Closeness
Centrality, Total-Degree
Select/Clear All
Select/Clear Visible
3 / 177 Selected, 26 / 177 Visible
< Back
Next >
Cancel
1
2
3
4
1. Type centrality
2. Select Centrality, Betweenness
3. Select Centrality, Closeness
4. Select Centrality, Total-degree
CASOS
June 2020
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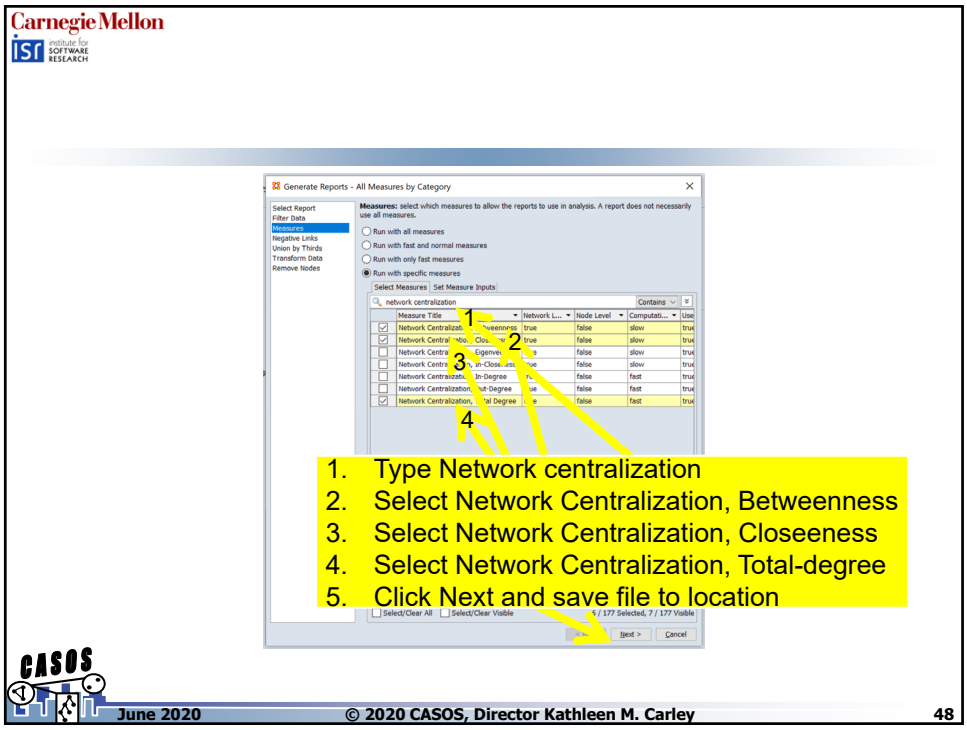
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Generate Reports - All Measures by Category
Select Report
Filter Data
Measures
Negative Links
Union by Thirds
Transform Data
Remove Nodes
Measures: select which measures to allow the reports to use in analysis. A report does not necessarily use all measures.
Run with all measures
Run with fast and normal measures
Run with only fast measures
Run with specific measures
Select Measures
Set Measure Inputs
network centralization
Contains
Measure Title
Network L...
Node Level
Computati...
Network Centralization, Betweenness
Network Centralization, Closeness
Network Centralization, In-Degree
Network Centralization, Out-Degree
Network Centralization, Total Degree
Select/Clear All
Select/Clear Visible
Next >
Cancel
1
2
3
4
1. Type Network centralization
2. Select Network Centralization, Betweenness
3. Select Network Centralization, Closeness
4. Select Network Centralization, Total-degree
5. Click Next and save file to location
CASOS
June 2020
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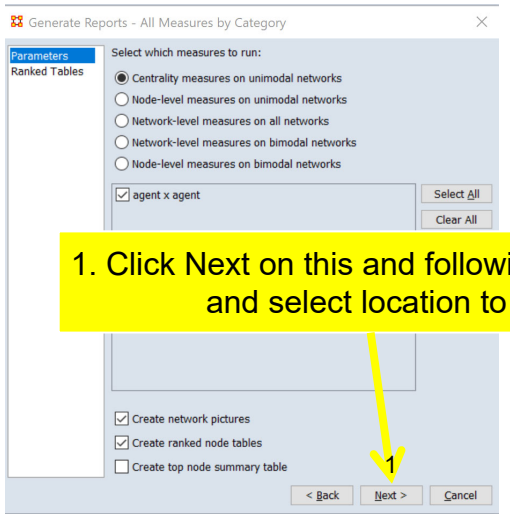
CASOS

<Your Name>

Generate one mode metrics from ORA



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

Generate one mode metrics from ORA

CUSTOM REPORT

Input data: startup_company

Start time: Fri May 25 15:33:46

Data Description

Table of Contents

Analysis for network agent x agent

Analysis for nodeset agent

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

View Analysis node class agent

<Your Name>

Generate one mode metrics from ORA

Agent-level Measures

Input data: startup_company

Start time: Fri May 25 15:33:46 2018

Return to previous page

Node-Level Measure / Input	Avg/Stddev	Min/Max	Min-Nodes/Max-Nodes
Centrality-Betweenness	0.200	0	Andrea, Chuck, Larry
Input: agent x agent	0.245	0.500	Andrea, Chuck
Centrality-Betweenness	1.200	0	Andrea, Chuck, Larry
Input: agent x agent	1.470	3	Andrea, Chuck
Centrality-Betweenness [inverted=true]	0.200	0	Andrea, Chuck, Larry
Input: agent x agent [inverted=true]	0.245	0.500	Andrea, Chuck
Centrality-Betweenness [inverted=true]	1.200	0	Andrea, Chuck, Larry
Input: agent x agent [inverted=true]	1.470	3	Andrea, Chuck
Centrality-Closeness	0.653	0.500	Andrea, Chuck
Input: agent x agent	0.134	0.800	Andrea, Chuck
Centrality-Closeness	0.163	0.125	Andrea, Chuck
Input: agent x agent	0.034	0.200	Andrea, Chuck
Centrality-Closeness [inverted=true]	0.653	0.500	Andrea, Chuck
Input: agent x agent [inverted=true]	0.134	0.800	Andrea, Chuck
Centrality-Closeness [inverted=true]	0.163	0.125	Andrea, Chuck
Input: agent x agent [inverted=true]	0.034	0.200	Andrea, Chuck
Centrality-Eccentricity	2.400	2	Andrea, Chuck, Larry
Input: agent x agent	0.490	3	Andrea, Chuck
Centrality-Eccentricity [inverted=true]	2.400	2	Andrea, Chuck, Larry
Input: agent x agent [inverted=true]	0.490	3	Andrea, Chuck
Centrality-In-Closeness	0.046	0.045	Andrea, Chuck
Input: agent x agent	7.247e-04	0.047	Andrea, Chuck
Centrality-In-Closeness	0.012	0.011	Andrea, Chuck
Input: agent x agent	1.812e-04	0.012	Andrea, Chuck
Centrality-In-Closeness [inverted=true]	0.046	0.045	Andrea, Chuck

Generate one mode metrics from ORA

CUSTOM REPORT

Input data: startup_company

Start time: Fri May 25 1

Data Description

View Analysis for network Agent by Agent

Table of Contents

Analysis for network agent x agent

Analysis for nodeset agent

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

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Generate one mode metrics from ORA

Network Agent x agent

Input data: agent x agent

Start time: Fri May 25 15:33:46 2018

Return to previous page

These measures take as input only the network agent x agent and output a single value (network-level measures) or a collection of values (node-level).

These measures output a single value.

Network-Level Measure	Value
Centrality-Radiality [inverted=true]	0
Centrality-Radiality	0
Characteristic Path Length	1.600
Characteristic Path Length [inverted=true]	1.600
Diameter [inverted=true]	3
Diameter	3
Diameter-Reachable	3
Diameter-Reachable [inverted=true]	3
Network Centralization-Betweenness [inverted=true]	0.375
Network Centralization-Betweenness	0.375
Network Centralization-Closeness [inverted=true]	0.428
Network Centralization-Closeness	0.428
Network Centralization-In-Closeness	0.002
Network Centralization-In-Closeness [inverted=true]	0.002
Network Centralization-Total Degree	0.417
Speed-Average [inverted=true]	0.625
Speed-Average	0.625
Speed-Minimum	0.333
Speed-Minimum [inverted=true]	0.333

Node-Level Measure	Avg/Stddev	Min/Max	Min-Nodes/Max-Nodes
Boundary Spanner-Potential	0.200	0	Andrea, Chuck, Larry
	0.245	0.500	Andrea, Chuck
Centrality-Betweenness	0.200	0	Andrea, Chuck, Larry

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Experiment 2b

Generate two mode network metrics from ORA report

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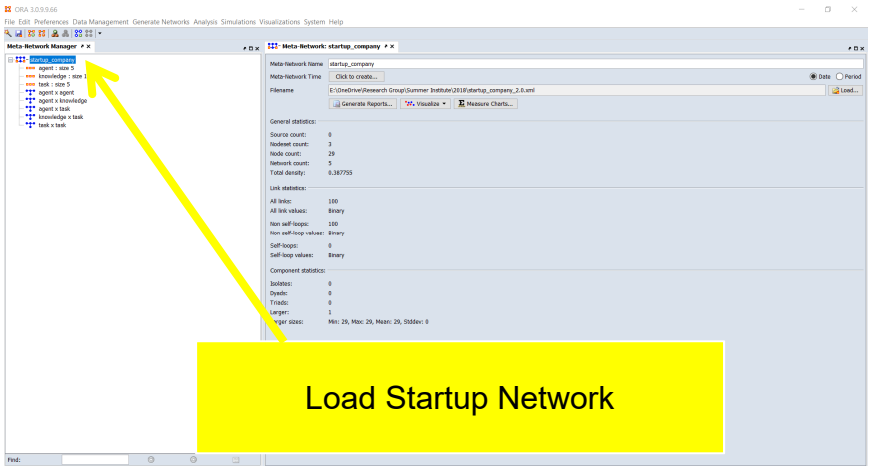
Generate two mode metrics from ORA



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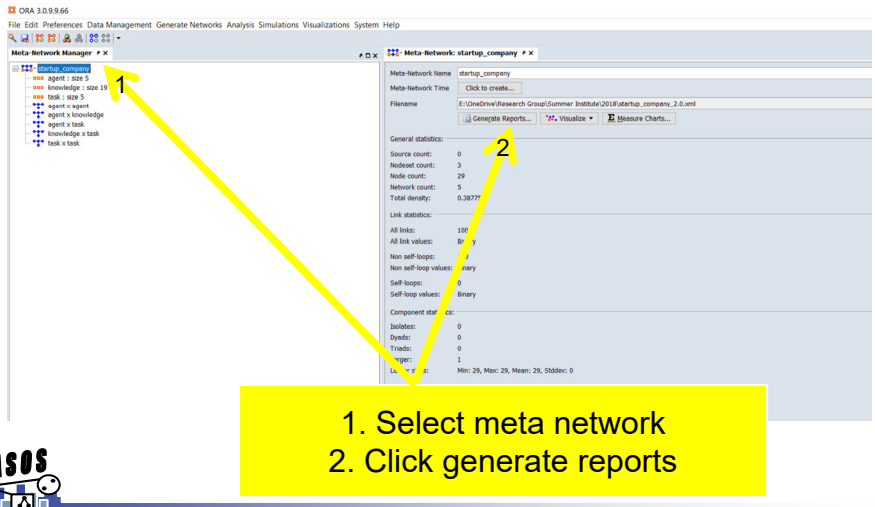
Generate two mode metrics from ORA



<Your Name>

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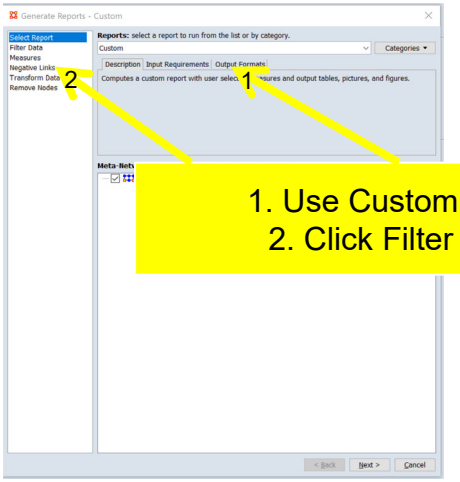
Generate two mode metrics from ORA



1. Use Custom report
2. Click Filter Data

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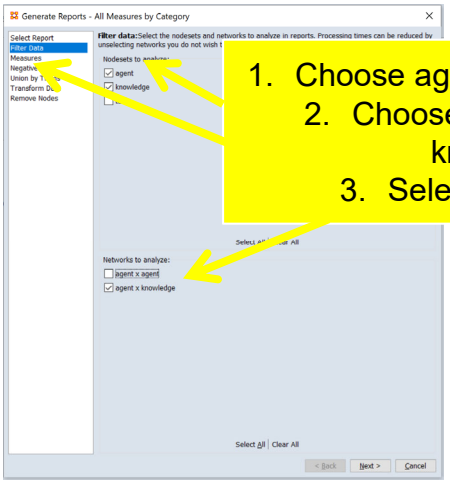
Generate two mode metrics from ORA



1. Choose agent and knowledg
2. Choose only agent by knowledge
3. Select Measures

<Your Name>

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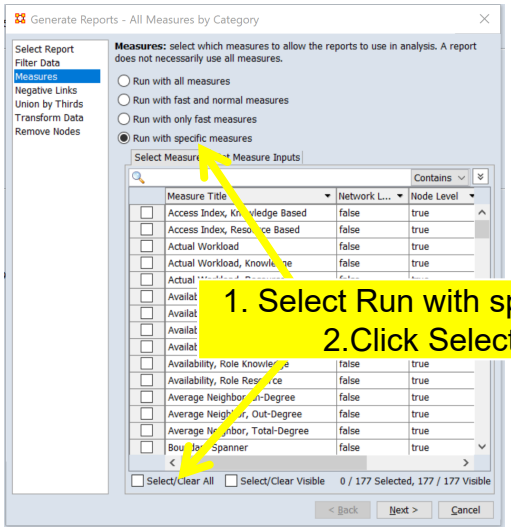
Generate two mode metrics from ORA



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

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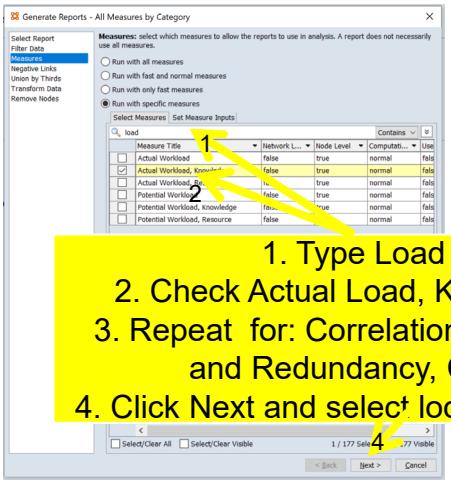
Generate two mode metrics from ORA



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

<Your Name>

Generate two mode metrics from ORA

CUSTOM REPORT

Input data: startup_company

Start time: Fri May 25 15:49:28

Data Description

View Analysis nodeset agent

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

Generate two mode metrics from ORA

Agent-level Measures

Input data: startup_company

Start time: Fri May 25 15:49:28 2018

Return to previous page

Node-Level Measure / Input	Avg/Stddev	Min/Max	Min-Nodes/Max-Nodes
Correlation-Cosine Similarity	0.495	0.372	Andrea
Input: agent x knowledge	0.071	0.577	Andrea
Correlation-Distinctiveness	0.495	0.461	Andrea
Input: agent x knowledge	0.018	0.513	Andrea
Correlation-Expertise	0.476	0.417	Andrea
Input: agent x knowledge	0.046	0.550	Andrea
Correlation-Resemblance	0.505	0.487	Andrea
Input: agent x knowledge	0.018	0.539	Andrea
Correlation-Jaccard Similarity	0.323	0.202	Andrea
Input: agent x knowledge	0.065	0.383	Andrea

Return to previous page

<Your Name>

Generate two mode metrics from ORA

CUSTOM REPORT

Input data: startup_company

Start time: Fri May 25 15:49

Data Description

View Analysis for network Agent by Knowledge

Table of Contents

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

Generate two mode metrics from ORA

Network Agent x knowledge

Input data: agent x knowledge

Start time: Fri May 25 15:49:28 2018

Return to previous page

These measures take as input only the network agent x knowledge and output a single value (network-level measures) or a collection of values (node-level).

These measures output a single value.

Network-Level Measure				Value
Redundancy-Column				0.368
Node-Level Measure	**Avg/Stddev**	**Min/Max**	**Min-Nodes/Max-Nodes**	
Correlation-Cosine Similarity	0.495	0.372	Andrea	
	0.071	0.577	Andrea	
Correlation-Distinctiveness	0.495	0.461	Andrea	
	0.018	0.513	Andrea	
Correlation-Expertise	0.476	0.417	Andrea	
	0.046	0.550	Andrea	
Correlation-Jaccard Similarity	0.323	0.202	Andrea	
	0.065	0.383	Andrea	
Correlation-Resemblance	0.505	0.487	Andrea	
	0.018	0.539	Andrea	

Return to previous page

<Your Name>

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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

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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.

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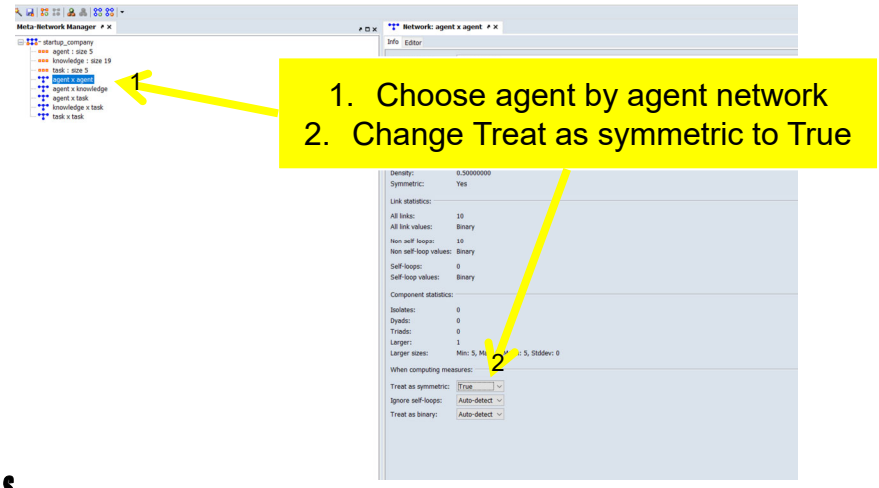
Hiding Network type Information from ORA Metrics



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Agenda

- Concepts
  - Types of networks
  - Types of metrics
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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

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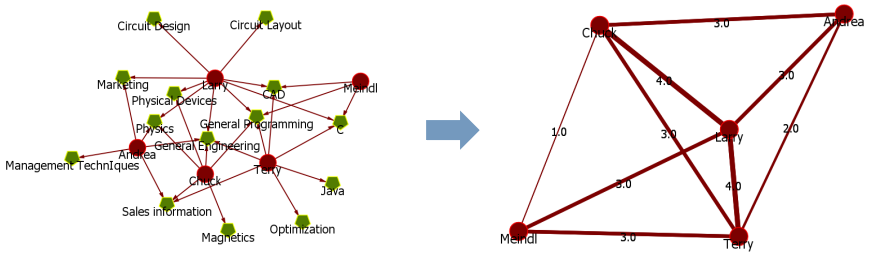
Folding Networks (2/2)



Person	Avg. Shared Knowledge
Larry	3.50
Terry	3.00
Chuck	2.75
Andrea	2.00
Meindl	1.75

<Your Name>

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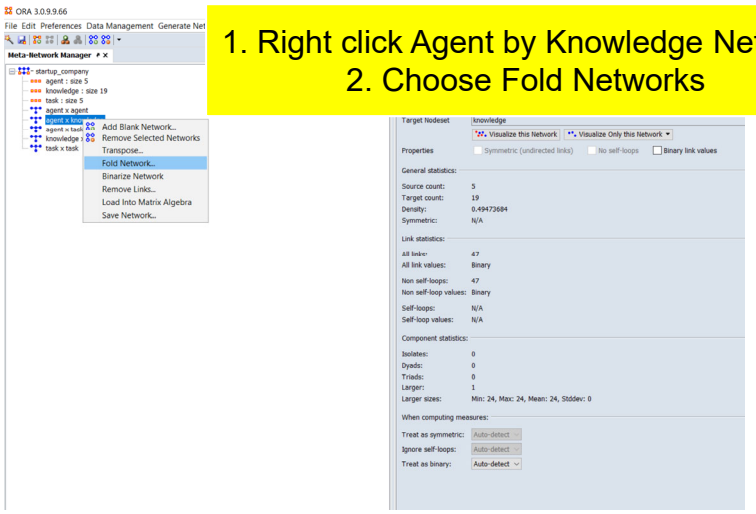
Folding Networks in ORA (1/4)



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

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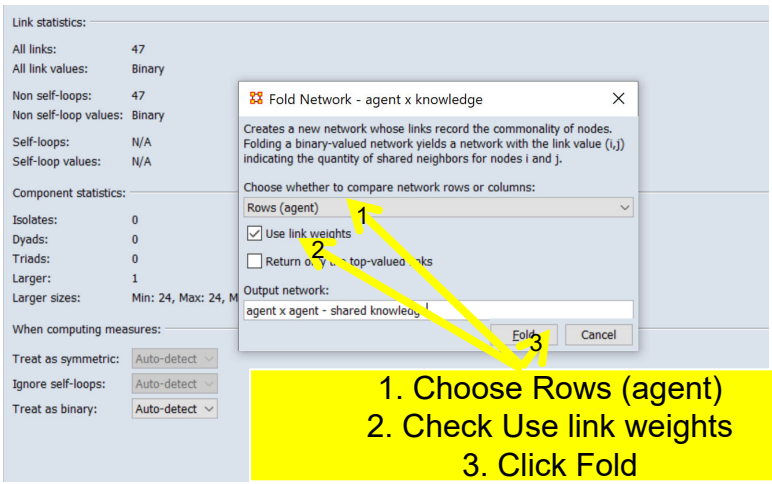
Folding Networks in ORA (2/4)



1. Choose Rows (agent)
2. Check Use link weights
3. Click Fold

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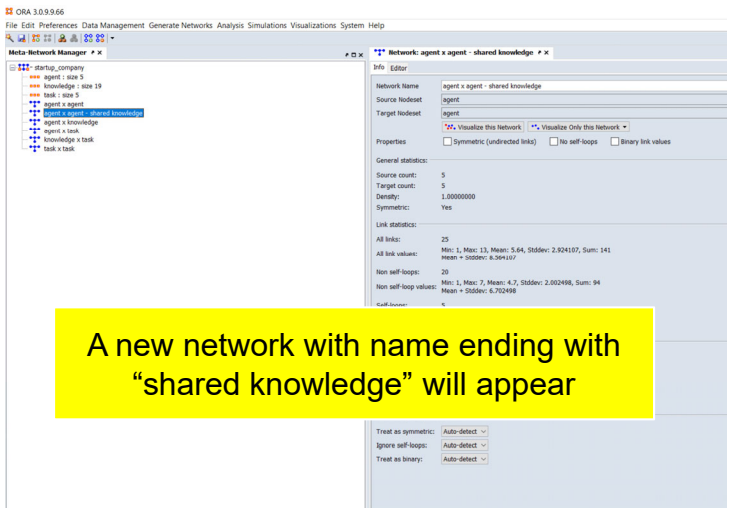
Folding Networks in ORA (3/4)



A new network with name ending with "shared knowledge" will appear

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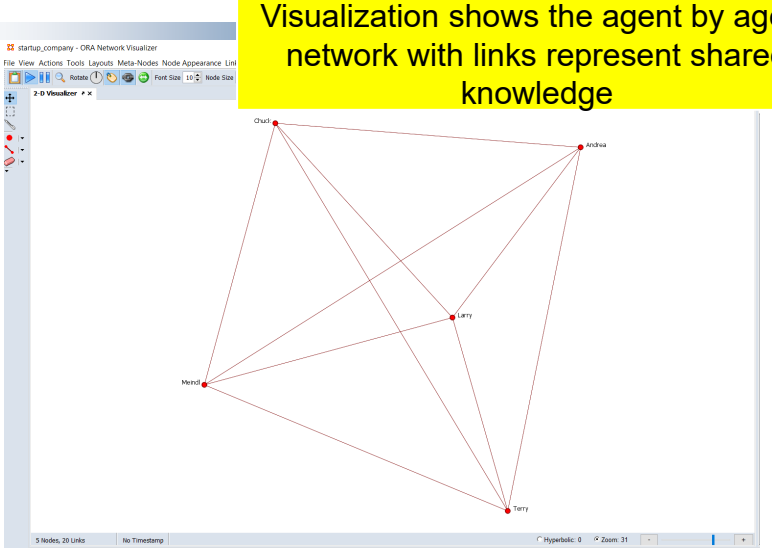
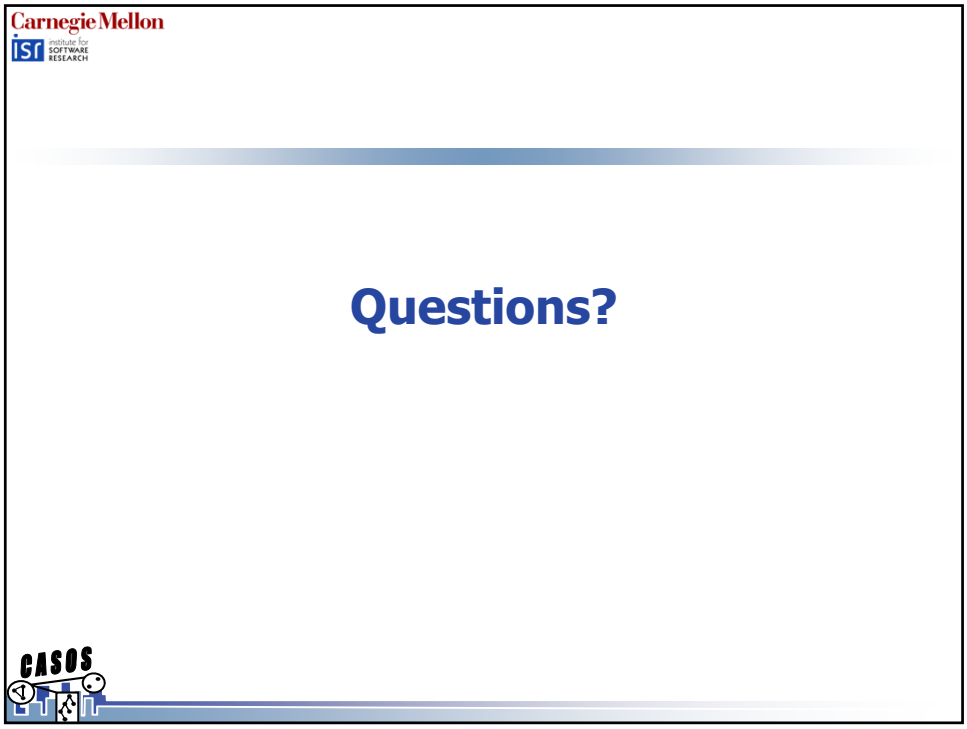
Folding Networks in ORA (4/4)

Visualization shows the agent by agent network with links represent shared knowledge



<Your Name>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Questions?
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