Investigating Statistical Mechanics of Complex Supply Chain Networks under Potential Risks

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Supply Chain Network
Risks in Supply Chain Network

- Delay of raw materials
- Disruption risk: employee strike, politics, or hurricanes
- Information System failures
- Demand forecast risk
- Intellectual property risk
- Procurement risk: fluctuating prices of raw materials
- Receivable risk: unable to get the money from customers
- Inventory risk: uncertainty in supply
- Capacity risk: machine breakdown or under utilization
Interesting Questions

- What is the most appropriate evolving model for constructing a complex supply chain network?
- How can we model the risks in a complex supply chain network?
- What are the criteria should we use to determine the robustness of a supply chain network?
- How can we improve the network robustness with the least redundancy?
Evolving model for A Supply Chain Network

- Intuitively the behavior of the actual supply chain network is similar to the Barabási and Albert model
  - Network growth
  - Preferential attachment

- However the probability of connection between a newly added node and the other existing node must be changed
  - \( P(k_i) = k_i / \Sigma k_i \rightarrow P(k_j) = (k_i + 1) / (\Sigma k_i + \Sigma N) \)
Evolving model for A Supply Chain Network

- Also there are some additional features for the supply chain network
  - Three types of node: supplier, manufacturer, and customer nodes
  - Adding supplier node at every year, manufacturer node every 6 months, and customer node every month
  - Attachment constraints: customer to manufacturer, manufacturer to supplier, and supplier to supplier
Evolving model for A Supply Chain Network

1st echelon

Supplier

2nd echelon

Manufacturer

3rd echelon

Customer

Customer

Customer

Customer

Customer
Statistical Mechanics:

- Total number of nodes
- Largest Connected Component (LCC)
- Connectivity ratio = LCC / Total number of nodes
- Average degree
- Average path length / inverse geodesic length
- Degree Distribution
Simulation of A Complex Supply Chain Network under Risk

- Simulation of the complex supply chain network using the proposed model
- The employee strike risk is selected and inserted into the model
- Parameters of the employee strike risk:
  - Probability of strike for each node is 0.05 during 90 days
  - The duration of a strike is a triangular distribution with parameter (1,3,10) days
  - The day where the strike begins is a uniform distribution between 1 and 90
- The simulations were done for both model without risk and under risk for 10 years of simulation time
Simulation: The basic model
Simulation: The model under risk

- Three types of model under risk
  - 1-attaching edge
  - 2-attaching edges (redundancy)
  - 3-attaching edges (high redundancy)

<table>
<thead>
<tr>
<th></th>
<th>Number of edges attached</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Size</td>
<td>143</td>
</tr>
<tr>
<td>LCC</td>
<td>110.2</td>
</tr>
<tr>
<td>Connectivity Ratio</td>
<td>0.771</td>
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<tr>
<td>Average Degree</td>
<td>1.407</td>
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<tr>
<td>Average Inverse Geodesic Length</td>
<td>0.177</td>
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Simulation: Largest Connected Component

Onyx Team
Conclusions & Future Works

- The simulations were done to investigate the statistical mechanics and robustness of the supply chain network under the potential risk.
- The results indicate that adding redundancy more than 2 attaching edges does not improve the network robustness any further.
- Some future works:
  - Agent-based systems for complex network modeling
  - How can we characterization of the potential risks
  - Design of topology for more robust networks