

Network Structure in a Multi-agent Economic Model

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How Does Structure Affect Network Dynamics?

We investigate the effect of structure on network robustness for a complex adaptive system (CAS). We present a systematic study to analyze structure's importance to a system. We are interested in a number of questions.

1. Does structure affect robustness to perturbations?
2. Are perturbations locally or globally dependent?
3. What happens when we combine structures?

Model Formulation

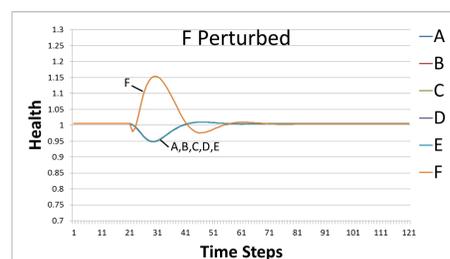
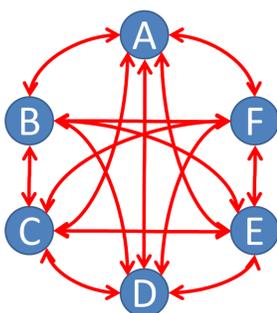
We use a CAS model developed at Sandia National Laboratories. Agents (entities) store, consume, and produce resources by interacting through markets to maintain viability. These rates are controlled by a 'health' metric. Perturbations are introduced by removing some amount of an entity's storage resource. The resulting dynamics are observed.



Full Network

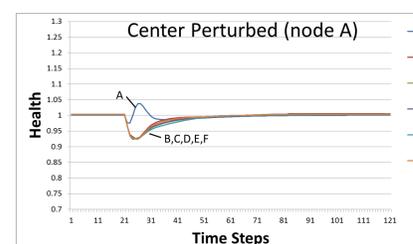
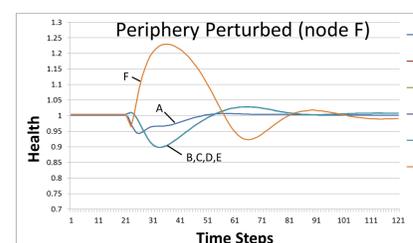
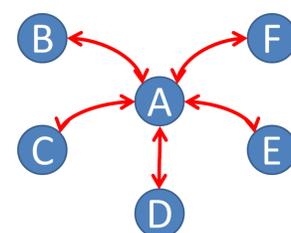
A fully connected network illustrates several general characteristics of a perturbation.

1. Perturbed sector sees a health gain
2. Oscillatory recovery



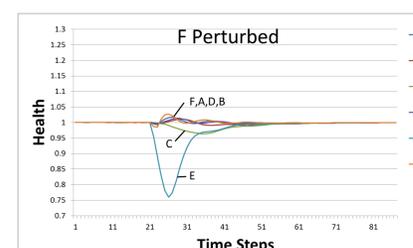
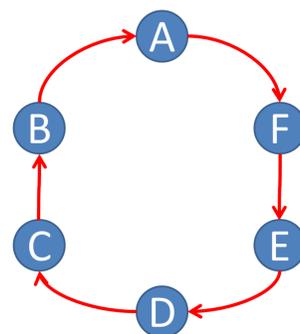
Hub Network

A hub network's response depends largely on where the perturbation occurs. A periphery perturbation has a response similar to a full network, while a center perturbation causes negative feedback, resulting in a short and small response.



Circular Network

In a circular network, instead of the perturbed node experiencing a large health gain, the downstream node sees a large health loss. We can conclude that shocks impact downstream nodes much more than upstream nodes.



Mixed Network

D perturbed:

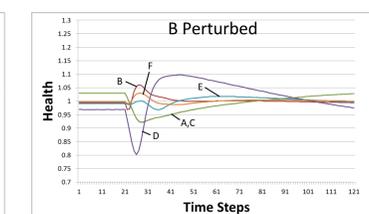
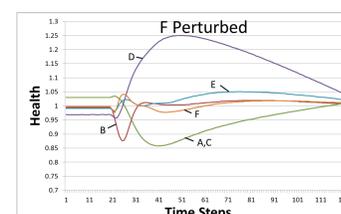
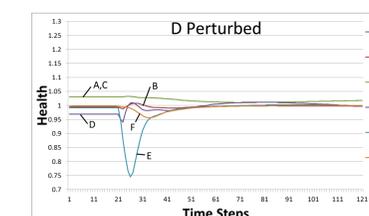
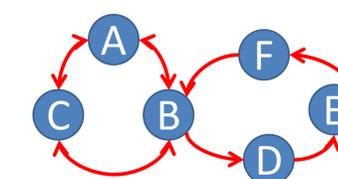
The network behaves like a circular network due to circular downstream structure.

F Perturbed:

The network has a unique response because the downstream structure is fully connected and one node away (B) from a circular network.

B Perturbed:

The network has a hybrid response because the perturbation enters both the full and circular networks immediately.



Key Conclusions

1. Network structure determines perturbation response.
2. Local structure has a large effect on perturbation dynamics.
3. Downstream structure, which is in the direction of the flow of resources, determines perturbation response.

Observing network responses to perturbations provides valuable insight into the dynamics of systems. Analysis of structure's role in network dynamics will allow us to design more robust networks.

References

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