Organizational Networks: Information Exchange and Robustness

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Principles of Complex Systems, Vols. 1, 2, & 3D CSYS/MATH 300, 303, & 394, 2022–2023 | @pocsvox

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Outline

Overview

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Goals Model Testing Results

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Overview

The basic idea/problem/motivation/history:

- Organizations as information exchange entities.
- 🚳 Catastrophe recovery.
- Solving ambiguous, ill-defined problems.
- Robustness as 'optimal' design feature.

A model of organizational networks:

- Network construction algorithm.
- Task specification.
- line algorithm.

Results:

Performance measures.

February, 1997:

Aisin (eye-sheen), maker of brake valve parts for Toyota, burns to ground.^[4]

- 4 hours supply ("just in time").
- 3 14,000 cars per day \rightarrow 0 cars per day.
- 6 months before new machines would arrive.
- 🗞 Recovered in 5 days.
- land and a study performed by Nishiguchi and Beaudet^[4] "Fractal Design: Self-organizing Links in Supply Chain" in "Knowledge Creation: A New Source of Value"

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February, 1997:

Some details:

- 36 suppliers, 150 subcontractors
- 🗞 50 supply lines
- lacktrian Sewing machine maker with no experience in car parts spent about 500 man hours refitting a milling machine to produce 40 valves a day.
- 🗞 Recovery depended on horizontal links which arguably provided:
 - 1. robustness
 - 2. searchability

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Some things fall apart:



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Motivation

Rebirth:

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Limited by existing resources,

🚓 Ambiguous (nothing is obvious),

problems that are:

\delta Unanticipated,

🚳 Unprecedented,

Critical for survival.

Frame:

Sollective solving of ambiguous problems

Recovery from catastrophe involves solving

Distributed (knowledge/people/resources),



Motivation

Ambiguity:

Let's modelify:

contacts.

occur.

Focus on robustness:

Why organizations exist:

- Question much less answer is not well understood.
- Back and forth search process rephrases question.
- leads to iterative process of query reformulation.
- Ambiguous tasks are inherently not decomposable.
- How do individuals collectively work on an ambiguous organization-scale problem?

Modeling ambiguous problems is hard...

Creative search is intrinsically inefficient.

1. Avoidance of individual failures.

Individuals need novel information and must

2. Survival of organization even when failures do

communicate with others outside of their usual

🚳 Model response instead...

How do we define ambiguity?

Real organizations—Extremes

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Ambiguous problems

Hierarchy:

- 🚳 Maximum efficiency,
- Suited to static environment, 🚳 Brittle.

Market:

- 🚳 Resilient,
- Suited to rapidly changing environment,
- Requires costless or low cost interactions.

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Organizations as efficient hierarchies @pocsvox Organizational

Ambiguous problem: Modelification

- Seconomics: Organizations \equiv Hierarchies. e.g., Radner (1993)^[5], Van Zandt (1998)^[7]
- A Hierarchies performing associative operations:

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Real organizations...

But real, complex organizations are in the middle...

"Heterarchy" David Stark. The Biology of Business: Decoding the Natural Laws of theEnterprise., New Series, 4, 153-, 1999.^[6]

Optimal network topologies for local search Organizational Networks Overview Models of organizations Modelification

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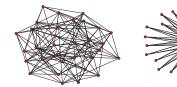
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'Optimal network topologies for local search with congestion" Guimerà et al.,

Phys. Rev. Lett., 89, 248701, 2002. [3]





- Parallel search and congestion.
- Queueing and network collapse.
- Exploration of random search mechanisms.

Optimal network topologies for local Organizational search ●●L=64 ◇◆L=96 ✓ L=128 \bigotimes Betweenness: β . ₽ □·□L=160 Polarization, A Polarization: Models of organizations Modelification maxβ $\pi =$ A = number oflinks. 0.1 0.2 0.3 0.4 Packet generation, p

- Soal: minimize average search time.
- ♣ Few searches ⇒ hub-and-spoke network.
- Many searches ⇒ decentralized network.
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Phase transition?

Desirable organizational qualities:

- 1. Low cost (requiring few links).
- 2. Scalability.
- 3. Ease of construction—existence is plausible.
- 4. Searchability.

5. 'Ultra-robustness':

- I Congestion robustness (Resilience to failure due to information
- exchange);
- II Connectivity robustness
 - (Recoverability in the event of failure).

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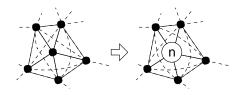
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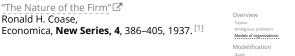


Ronald H. Coase,

"The Nature of the Firm" 🖸

More efficient for individuals to cooperate outside of the market.





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Searchability

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Model-addition of links

Core-periphery networks (m = 6):

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Small world problem:

- 🗞 Can individuals pass a message to a target individual using only personal connections?
- A Yes, large scale networks searchable if nodes have References identities.

"Information exchange and the robustness of organizational networks"

Proc. Natl. Acad. Sci., 100, 12516-12521,

 \bigcirc Choose *m* links according to a two parameter

ldentity and Search in Social Networks," Watts, Dodds, & Newman, 2002.^[8]

Dodds, Watts, and Sabel,

2003. [2]

🚳 Edited by Harrison White 🗹

line branching ratio b \bigcirc depth L

Onderlying hierarchy:

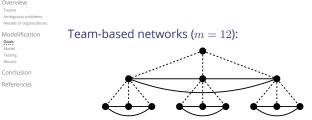
N-1 links & Additional informal ties:

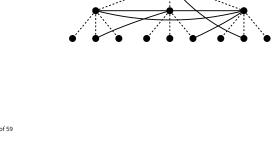
Formal organizational structure:

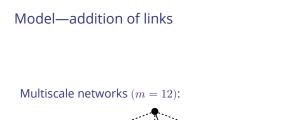
 $\stackrel{\cdot}{\bigotimes}$ $N = (b^L - 1)/(b - 1)$ nodes

probability distribution $0 \le m \le (N-1)(N-2)/2$

Model—underlying hierarchy







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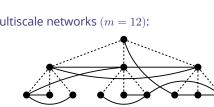
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Modelification





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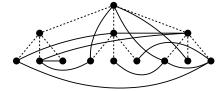
 x_2

 d_1

 d_2





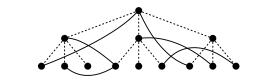




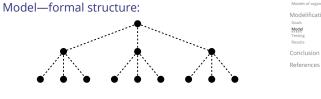
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livisional networks (m = 6):



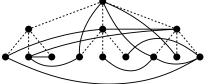
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 $b = 3, \quad L = 3, \quad N = 13$







Model—addition of links

Model—addition of links

Model—construction

Link addition probability:

 $P(D,d_1,d_2) \propto e^{-D/\lambda} e^{-f(d_1,d_2)/\zeta}$

- \clubsuit First choose (D, d_1, d_2) .
- $\label{eq:rescaled} \& \text{ Randomly choose } (y, x_1, x_2) \text{ given } (D, d_1, d_2).$
- Choose links without replacement.

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Model—construction

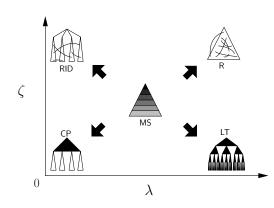
Requirements for $f(d_1, d_2)$:

- 1. $f \ge 0$ for $d_1 + d_2 \ge 2$
- 2. *f* increases monotonically with d_1, d_2 .
- 3. $f(d_1, d_2) = f(d_2, d_1)$.
- 4. *f* is maximized when $d_1 = d_2$.

Simple function satisfying 1-4:

 $f(d_1,d_2)=(d_1^2+d_2^2-2)^{1/2}$ $\Rightarrow P(y,x_1,x_2) \propto e^{-D/\lambda} e^{-(d_1^2+d_2^2-2)^{1/2}/\zeta}$

Model—limiting cases



Message passing pattern

- \mathfrak{F} Each of T time steps, each node generates a message with probability μ .
- Recipient of message chosen based on distance from sender.
- 2

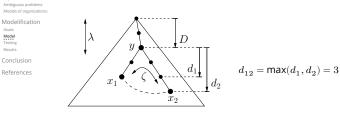
 $P(\text{recipient at distance } d) \propto e^{-d/\xi}$.

- 1. ξ = measure of uncertainty;
- 2. $\xi = 0$: local message passing;
- 3. $\xi = \infty$: random message passing.

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Message passing pattern:

Distance d_{12} between two nodes x_1 and x_2 :



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Message passing pattern

Simple message routing algorithm:

- 🗞 Look ahead one step: always choose neighbor closest to recipient node.
 - 1. Nodes understand hierarchy.

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Interpretations:

- 1. Sender knows specific recipient.
- 2. Sender requires certain kind of recipient.
- 3. Sender seeks specific information but recipient unknown.
- 4. Sender has a problem but information/recipient unknown.

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Message passing pattern

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Performance:

& Measure Congestion Centrality ρ_i , fraction of messages passing through node <i>i</i> .	
\delta Similar to betweenness centrality.	
🗞 However: depends on	

1. Search algorithm;

2. Task specification (μ , ξ).

& Congestion robustness comes from minimizing ρ_{max} .

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Solution Underlying hierarchy: b = 5, L = 6, N = 3096;

- \mathfrak{F} Number of informal ties: m = N. & Link addition algorithm: $\lambda = \zeta = 0.5$.
- & Message passing: $\xi = 1$, $\mu = 10/N$, T = 1000.

Message passing pattern

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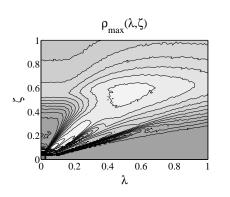
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A Pseudo-global knowledge:

- 2. Nodes know only local informal ties.
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Results—congestion robustness



Results—Maximum firm size

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Congestion may increase with size of network.

- \Re Fix rate of message passing (μ) and Message pattern (ξ).
- line and add more levels.
- & Individuals have limited capacity \Rightarrow limit to firm size.

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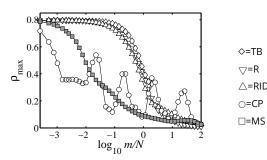
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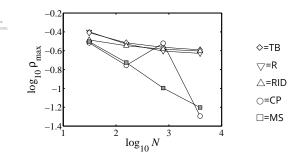
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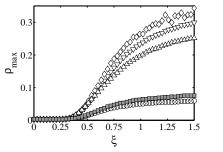
Results-varying number of links added:



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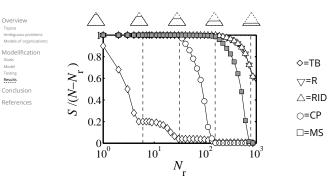
Connectivity	Robustness

Inducing catastrophic failure:

- \Re Remove N_r nodes and measure relative size of largest component $C = S/(N - N_r)$.
- Four deletion sequences:
 - 1. Top-down;
 - 2. Random;
 - 3. Hub;
 - 4. Cascading failure.

Results largely independent of sequence.





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lems zations:	Feature	Congestion Robustness	Connectivity Robustness	Scalability	Overview Toyota Ambiguous problems Models of organizations:
on	Core-periphery	good	average	average	Modelification Goals Model Testing
	Random	poor	good	poor	Results Conclusion
	Rand. Interdivisional	poor	good	poor	References
	Team-based	poor	poor	poor	
	Multiscale	good	good	good	



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Multi-scale networks:

- 1. Possess good Congestion Robustness and Connectivity Robustness \Rightarrow Ultra-robust;
- 2. Scalable;
 - 3. Relatively insensitive to parameter choice;
 - Above suggests existence of multi-scale structure is plausible.





Scalability in complete uncertainty: $\xi = \infty$

Conclusary moments

- Foregoing is an attempt to model what organizations might look like beyond simple hierarchies (2003).
- Possible work: develop 'bottom up' model of organizational networks based on social search, identity (emergent searchability).
- Balance of generalists versus specialists—how many middle managers does an organization need?
- Still a need for data on real organizations...

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