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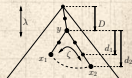
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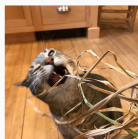
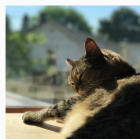
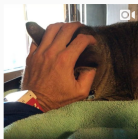
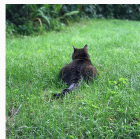
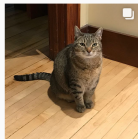
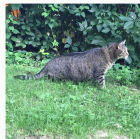
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The basic idea/problem/motivation/history:



Organizations as information exchange entities.



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The basic idea/problem/motivation/history:



Organizations as information exchange entities.



Catastrophe recovery.



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The basic idea/problem/motivation/history:

 Organizations as information exchange entities.

 Catastrophe recovery.

 Solving ambiguous, ill-defined problems.



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The basic idea/problem/motivation/history:

 Organizations as information exchange entities.

 Catastrophe recovery.

 Solving ambiguous, ill-defined problems.

 Robustness as 'optimal' design feature.



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The basic idea/problem/motivation/history:

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- Catastrophe recovery.
- Solving ambiguous, ill-defined problems.
- Robustness as 'optimal' design feature.

A model of organizational networks:

- Network construction algorithm.



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The basic idea/problem/motivation/history:

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- Solving ambiguous, ill-defined problems.
- Robustness as 'optimal' design feature.

A model of organizational networks:

- Network construction algorithm.
- Task specification.



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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.
-  Message routing algorithm.



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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.



Message routing algorithm.

Results:



Performance measures.



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February, 1997:

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

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February, 1997:

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 4 hours supply (“just in time”).

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14,000 cars per day $\rightarrow$ 0 cars per day.



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6 months before new machines would arrive.



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4 hours supply (“just in time”).



14,000 cars per day $\rightarrow$ 0 cars per day.



6 months before new machines would arrive.



Recovered in 5 days.



February, 1997:

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



4 hours supply (“just in time”).



14,000 cars per day $\rightarrow$ 0 cars per day.



6 months before new machines would arrive.



Recovered in 5 days.



Case study performed by Nishiguchi and Beaudet ^[4]

“Fractal Design: Self-organizing Links in Supply Chain”
in “Knowledge Creation: A New Source of Value”



February, 1997:

Some details:



36 suppliers, 150 subcontractors

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Some details:

 36 suppliers, 150 subcontractors

 50 supply lines



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Some details:

 36 suppliers, 150 subcontractors

 50 supply lines

 Sewing machine maker with no experience in car parts spent about 500 man hours refitting a milling machine to produce 40 valves a day.



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Some details:

 36 suppliers, 150 subcontractors

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 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:



 36 suppliers, 150 subcontractors



50 supply lines



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



February, 1997:

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Some details:

 36 suppliers, 150 subcontractors

 50 supply lines

 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



Some things fall apart:



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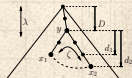
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Motivation

Recovery from catastrophe involves solving problems that are:

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Motivation

Recovery from catastrophe involves solving problems that are:



Unanticipated,

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Motivation

Recovery from catastrophe involves solving problems that are:

- Unanticipated,
- Unprecedented,

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Motivation

Recovery from catastrophe involves solving problems that are:

- 🧱 Unanticipated,
- 🧱 Unprecedented,
- 🧱 Ambiguous (nothing is obvious),

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Motivation

Recovery from catastrophe involves solving problems that are:

- 🧱 Unanticipated,
- 🧱 Unprecedented,
- 🧱 Ambiguous (nothing is obvious),
- 🧱 Distributed (knowledge/people/resources),



Motivation

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Recovery from catastrophe involves solving problems that are:

- Unanticipated,
- Unprecedented,
- Ambiguous (nothing is obvious),
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- Limited by existing resources,



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Recovery from catastrophe involves solving problems that are:



Unanticipated,



Unprecedented,



Ambiguous (nothing is obvious),



Distributed (knowledge/people/resources),



Limited by existing resources,



Critical for survival.



Motivation

Recovery from catastrophe involves solving problems that are:

- Unanticipated,
- Unprecedented,
- Ambiguous (nothing is obvious),
- Distributed (knowledge/people/resources),
- Limited by existing resources,
- Critical for survival.

Frame:

- Collective solving of ambiguous problems



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Ambiguity:



Question much less answer is not well understood.



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Ambiguity:



Question much less answer is not well understood.



Back and forth search process rephrases question.



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Ambiguity:

- ❏ Question much less answer is not well understood.
- ❏ Back and forth search process rephrases question.
- ❏ Leads to iterative process of query reformulation.



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Ambiguity:



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.



Ambiguity:

- 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?



Ambiguity:

- 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?
- How do we define ambiguity?



Let's modelify:

Modeling ambiguous problems is hard...

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Let's modelify:

Modeling ambiguous problems is hard...



Model response instead...



Let's modelify:

Modeling ambiguous problems is hard...



Model response instead...



Individuals need novel information and must communicate with others outside of their usual contacts.



Let's modelify:

Modeling ambiguous problems is hard...

- Model response instead...
- Individuals need novel information and must communicate with others outside of their usual contacts.
- Creative search is intrinsically inefficient.

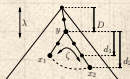


Let's modelify:

Modeling ambiguous problems is hard...

- Model response instead...
- Individuals need novel information and must communicate with others outside of their usual contacts.
- Creative search is intrinsically inefficient.

Focus on robustness:



Let's modelify:

Modeling ambiguous problems is hard...

- Model response instead...
- Individuals need novel information and must communicate with others outside of their usual contacts.
- Creative search is intrinsically inefficient.

Focus on robustness:

- Avoidance of individual failures.



Let's modelify:

Modeling ambiguous problems is hard...

-  Model response instead...
-  Individuals need novel information and must communicate with others outside of their usual contacts.
-  Creative search is intrinsically inefficient.

Focus on robustness:

1. Avoidance of individual failures.
2. Survival of organization even when failures do occur.



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Why organizations exist:



“The Nature of the Firm” , Ronald H. Coase, Economica,
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Why organizations exist:



“The Nature of the Firm” , Ronald H. Coase, *Economica*,
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Notion of Transaction Costs .



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Notion of Transaction Costs .



More efficient for individuals to cooperate outside of the market.



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Why organizations exist:



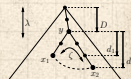
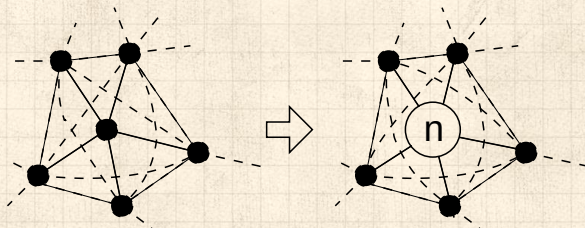
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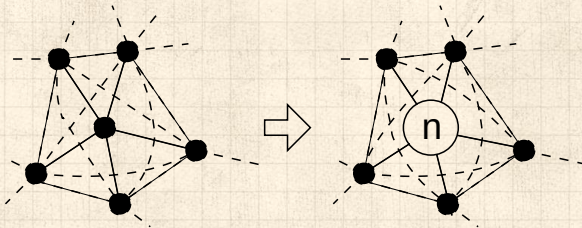
“The Nature of the Firm” [↗](#), Ronald H. Coase, *Economica*,
New Series, 4, 386–405, 1937. ^[1]



Notion of Transaction Costs [↗](#).



More efficient for individuals to cooperate outside of the market.



Coase [↗](#) had a solid career [↗](#).



Real organizations—Extremes

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Hierarchy:



Maximum efficiency,



Suited to static environment,



Brittle.



Real organizations—Extremes

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Hierarchy:

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

Market:

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



Organizations as efficient hierarchies

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 Economics: Organizations $\equiv$ Hierarchies.

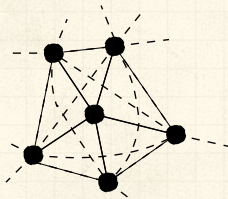
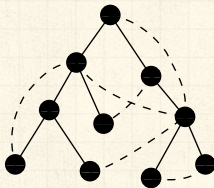
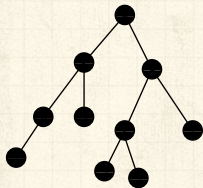
 e.g., Radner (1993) ^[5], Van Zandt (1998) ^[7]

 Hierarchies performing associative operations:



Real organizations...

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



“Heterarchy” 

David Stark,

The Biology of Business: Decoding the Natural Laws
of the Enterprise., **New Series**, 4, 153–, 1999. ^[6]



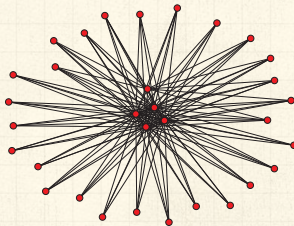
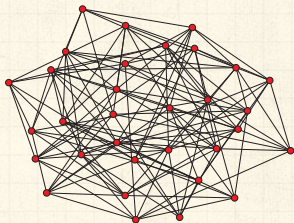
Optimal network topologies for local search



“Optimal network topologies for local search with congestion” 

Guimerà et al.,

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



Parallel search and congestion.



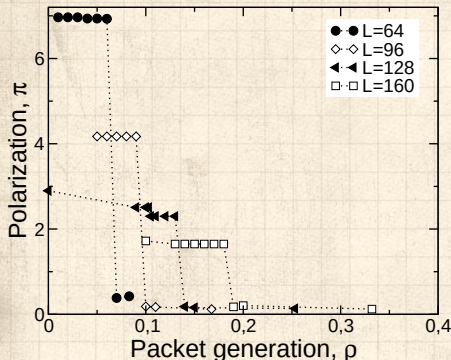
Queueing and network collapse.



Exploration of random search mechanisms.



Optimal network topologies for local search



Betweenness: β .



Polarization:

$$\pi = \frac{\max \beta}{\langle \beta \rangle} - 1.$$



L = number of links.



Goal: minimize average search time.



Few searches $\Rightarrow$ hub-and-spoke network.



Many searches $\Rightarrow$ decentralized network.



Phase transition?



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Desirable organizational qualities:

1. Low cost (requiring few links).

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Desirable organizational qualities:

1. Low cost (requiring few links).
2. Scalability.

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Desirable organizational qualities:

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



Desirable organizational qualities:

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



Desirable organizational qualities:

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3. Ease of construction—existence is plausible.
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5. 'Ultra-robustness':



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);



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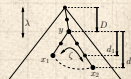
References

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).



Small world problem:

- Can individuals pass a message to a target individual using only personal connections?
- Yes, large scale networks searchable if nodes have **identities**.
- “Identity and Search in Social Networks,” Watts, Dodds, & Newman, 2002. [8]



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branching ratio b

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Formal organizational structure:



Underlying hierarchy:



branching ratio b



depth L



$N = (b^L - 1)/(b - 1)$ nodes

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Formal organizational structure:



Underlying hierarchy:



branching ratio b



depth L



$N = (b^L - 1)/(b - 1)$ nodes



$N - 1$ links



Additional informal ties:





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Formal organizational structure:



Underlying hierarchy:



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Additional informal ties:



Choose m links according to a two parameter probability
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Formal organizational structure:



Underlying hierarchy:



branching ratio b



depth L



$N = (b^L - 1)/(b - 1)$ nodes



$N - 1$ links



Additional informal ties:



Choose m links according to a two parameter probability distribution



$0 \leq m \leq (N - 1)(N - 2)/2$



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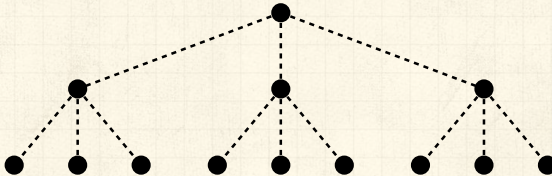
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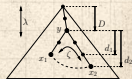
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Model—formal structure:



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



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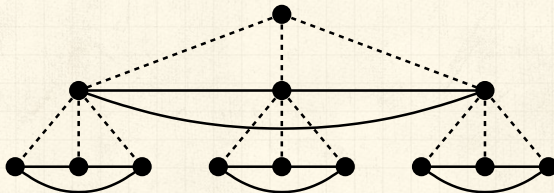
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Team-based networks ($m = 12$):



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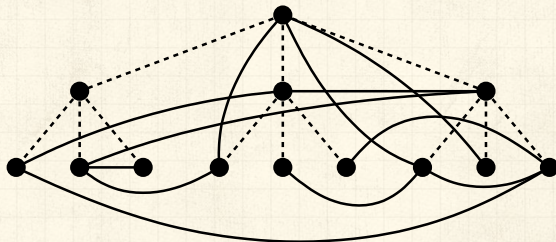
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Random networks ($m = 12$):



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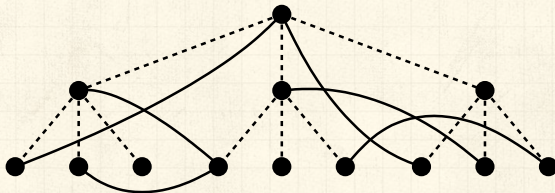
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Random interdivisional networks ($m = 6$):



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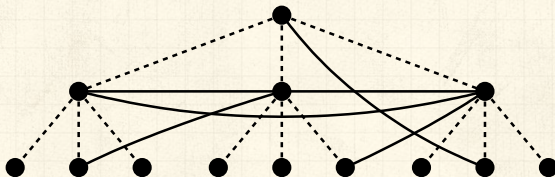
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Core-periphery networks ($m = 6$):



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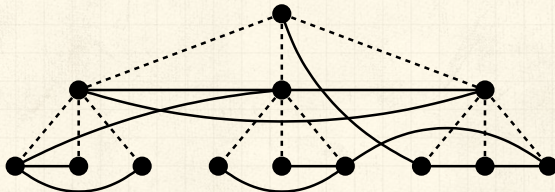
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Multiscale networks ($m = 12$):



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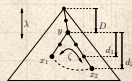
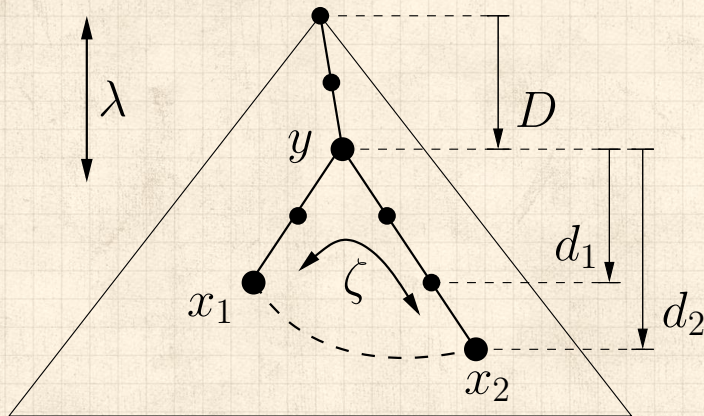
Model

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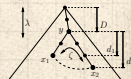
 Link addition probability:

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

 First choose (D, d_1, d_2) .

 Randomly choose (y, x_1, x_2) given (D, d_1, d_2) .

 Choose links without replacement.



Model—construction

Requirements for $f(d_1, d_2)$:

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Requirements for $f(d_1, d_2)$:

1. $f \geq 0$ for $d_1 + d_2 \geq 2$



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Requirements for $f(d_1, d_2)$:

1. $f \geq 0$ for $d_1 + d_2 \geq 2$
2. f increases monotonically with d_1, d_2 .



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Requirements for $f(d_1, d_2)$:

1. $f \geq 0$ for $d_1 + d_2 \geq 2$
2. f increases monotonically with d_1, d_2 .
3. $f(d_1, d_2) = f(d_2, d_1)$.



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Requirements for $f(d_1, d_2)$:

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2. f increases monotonically with d_1, d_2 .
3. $f(d_1, d_2) = f(d_2, d_1)$.
4. f is minimized when $d_1 = d_2$ (homophily)



Requirements for $f(d_1, d_2)$:

1. $f \geq 0$ for $d_1 + d_2 \geq 2$
2. f increases monotonically with d_1, d_2 .
3. $f(d_1, d_2) = f(d_2, d_1)$.
4. f is minimized when $d_1 = d_2$ (homophily)

Simple function satisfying 1–4:

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



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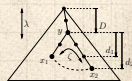
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Message passing pattern



Each of T time steps, each node generates a message with probability μ .

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Message passing pattern



Each of T time steps, each node generates a message with probability μ .



Recipient of message chosen based on distance from sender.



Message passing pattern



Each of T time steps, each node generates a message with probability μ .



Recipient of message chosen based on distance from sender.



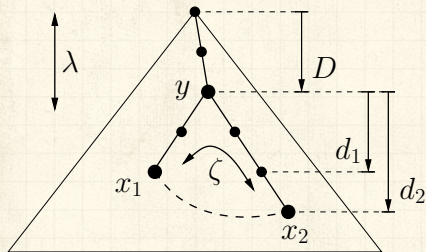
$$P(\text{recipient at distance } d) \propto e^{-d/\xi}.$$

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



Message passing pattern:

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



$$d_{12} = \max(d_1, d_2) = 3$$



Measure unchanged with presence of informal ties.



Message passing pattern

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Simple message routing algorithm:



Look ahead one step: always choose neighbor closest to recipient node.



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Simple message routing algorithm:

 Look ahead one step: always choose neighbor closest to recipient node.

 Pseudo-global knowledge:

1. Nodes understand hierarchy.
2. Nodes know only local informal ties.



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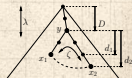
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Interpretations:

1. Sender knows specific recipient.



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Interpretations:

1. Sender knows specific recipient.
2. Sender requires certain kind of recipient.



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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.



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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.



Message passing pattern

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Performance:



Measure Congestion Centrality ρ_i , fraction of messages passing through node i .



Performance:

- Measure Congestion Centrality ρ_i , fraction of messages passing through node i .
- Similar to betweenness centrality.



Message passing pattern

Performance:

- Measure Congestion Centrality ρ_i , fraction of messages passing through node i .
- Similar to betweenness centrality.
- However: depends on
 1. Search algorithm;



Message passing pattern

Performance:

- Measure Congestion Centrality ρ_i , fraction of messages passing through node i .
- Similar to betweenness centrality.
- However: depends on
 - Search algorithm;
 - Task specification (μ, ξ) .



Message passing pattern

Performance:

- Measure Congestion Centrality ρ_i , fraction of messages passing through node i .
- Similar to betweenness centrality.
- However: depends on
 - Search algorithm;
 - Task specification (μ, ξ) .
- Congestion robustness comes from minimizing $\rho_{\max}$.



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Parameter settings (unless varying):

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



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Parameter settings (unless varying):

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Number of informal ties: $m = N$.



Performance testing:

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Parameter settings (unless varying):

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

Number of informal ties: $m = N$.

Link addition algorithm: $\lambda = \zeta = 0.5$.



Performance testing:

Parameter settings (unless varying):

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

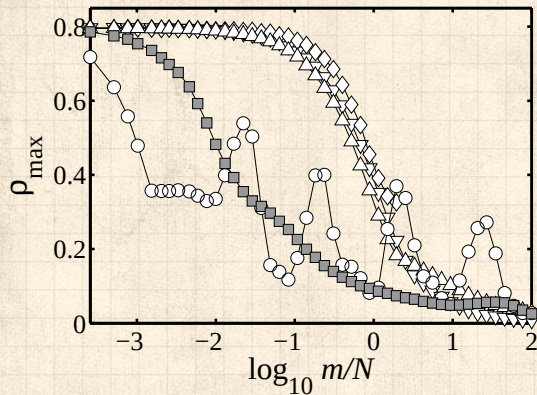
Number of informal ties: $m = N$.

Link addition algorithm: $\lambda = \zeta = 0.5$.

Message passing: $\xi = 1, \mu = 10/N, T = 1000$.



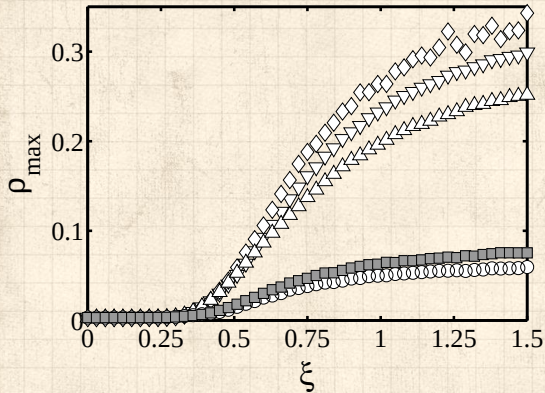
Results—varying number of links added:



◇=TB
▽=R
△=RID
○=CP
□=MS



Results—varying message passing pattern



$\diamond$ =TB

∇ =R

$\triangle$ =RID

$\circ$ =CP

$\square$ =MS



Results—Maximum firm size

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Congestion may increase with size of network.



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Congestion may increase with size of network.



Fix rate of message passing (μ) and Message pattern (ξ).



Results—Maximum firm size

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Congestion may increase with size of network.



Fix rate of message passing (μ) and Message pattern (ξ).



Fix branching ratio of hierarchy and add more levels.



Results—Maximum firm size

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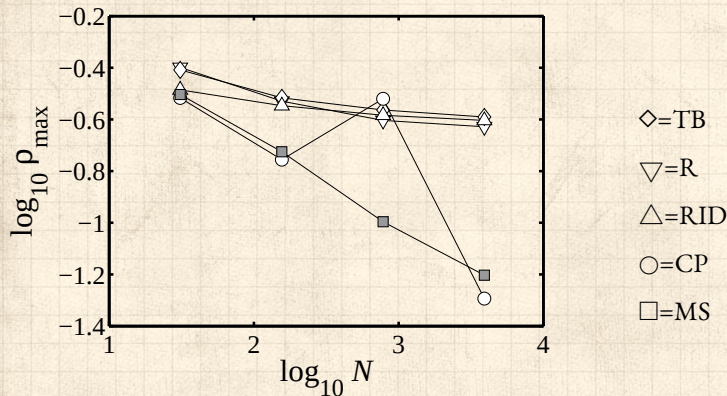
Conclusion

References

- 🧱 Congestion may increase with size of network.
- 🧱 Fix rate of message passing (μ) and Message pattern (ξ).
- 🧱 Fix branching ratio of hierarchy and add more levels.
- 🧱 Individuals have limited capacity $\Rightarrow$ limit to firm size.



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



Connectivity Robustness

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Inducing catastrophic failure:



Remove N_r nodes and measure relative size of largest component

$$C = S/(N - N_r).$$



Inducing catastrophic failure:

 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.



Inducing catastrophic failure:

 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.





Summary of results

Feature	Congestion Robustness	Connectivity Robustness	Scalability
Core-periphery	good	average	average
Random	poor	good	poor
Rand. Interdivisional	poor	good	poor
Team-based	poor	poor	poor
Multiscale	good	good	good



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Multi-scale networks:

1. Possess good Congestion Robustness and Connectivity Robustness
⇒ Ultra-robust;



Conclusory moments

Multi-scale networks:

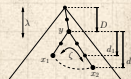
1. Possess good Congestion Robustness and Connectivity Robustness
⇒ Ultra-robust;
2. Scalable;



Conclusory moments

Multi-scale networks:

1. Possess good Congestion Robustness and Connectivity Robustness
⇒ Ultra-robust;
2. Scalable;
3. Relatively insensitive to parameter choice;



Conclusory moments

Multi-scale networks:

1. Possess good Congestion Robustness and Connectivity Robustness
⇒ Ultra-robust;
2. Scalable;
3. Relatively insensitive to parameter choice;



Above suggests existence of multi-scale structure is plausible.



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Foregoing is an attempt to model what organizations might look like beyond simple hierarchies (2003).



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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).



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- 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?



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- 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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