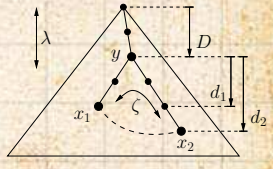
Organizational Networks: Information Exchange and Robustness

Complex Networks | @networksvox
CSYS/MATH 303, Spring, 2016

Prof. Peter Dodds | @peterdodds

Dept. of Mathematics & Statistics | Vermont Complex Systems Center
Vermont Advanced Computing Core | University of Vermont

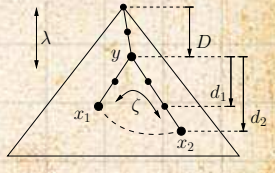


Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

Licensed under the *Creative Commons Attribution-NonCommercial-ShareAlike 3.0 License*.

These slides are brought to you by:

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References



The UNIVERSITY of VERMONT

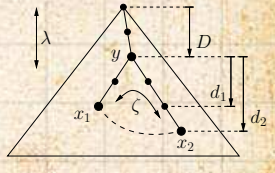
Outline

Overview
- Toyota
- Ambiguous problems
- Models of organizations:

Modelification
- Goals
- Model
- Testing
- Results

Conclusion

References



Overview

The basic idea/problem/motivation/history:

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

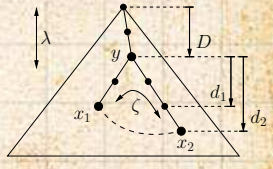
A model of organizational networks:

- Network construction algorithm.
- Task specification.
- Message routing algorithm.

Results:

- Performance measures.

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References



Overview

The basic idea/problem/motivation/history:

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

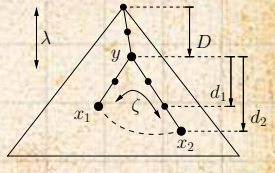
A model of organizational networks:

- Network construction algorithm.
- Task specification.
- Message routing algorithm.

Results:

- Performance measures.

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References



Overview

The basic idea/problem/motivation/history:

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

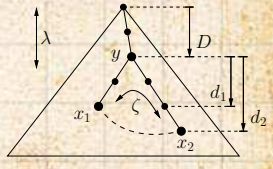
A model of organizational networks:

- Network construction algorithm.
- Task specification.
- Message routing algorithm.

Results:

- Performance measures.

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References



Overview

The basic idea/problem/motivation/history:

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

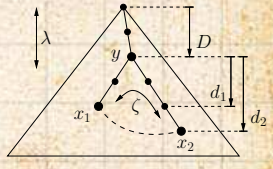
A model of organizational networks:

- Network construction algorithm.
- Task specification.
- Message routing algorithm.

Results:

- Performance measures.

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References



Overview

The basic idea/problem/motivation/history:

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

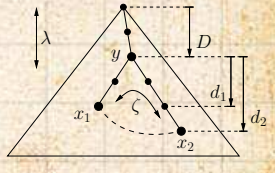
A model of organizational networks:

- Network construction algorithm.
- Task specification.
- Message routing algorithm.

Results:

- Performance measures.

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References



Overview

The basic idea/problem/motivation/history:

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

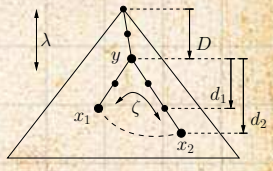
A model of organizational networks:

- Network construction algorithm.
- Task specification.
- Message routing algorithm.

Results:

- Performance measures.

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References



Overview

The basic idea/problem/motivation/history:

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

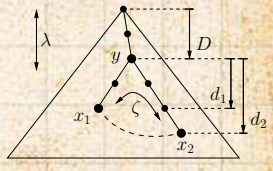
A model of organizational networks:

- Network construction algorithm.
- Task specification.
- Message routing algorithm.

Results:

- Performance measures.

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References



Overview

The basic idea/problem/motivation/history:

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

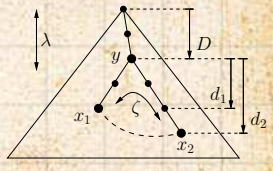
A model of organizational networks:

- Network construction algorithm.
- Task specification.
- Message routing algorithm.

Results:

- Performance measures.

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References



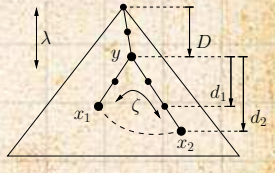
Outline

Overview
- Toyota
- Ambiguous problems
- Models of organizations:

Modelification
- Goals
- Model
- Testing
- Results

Conclusion

References



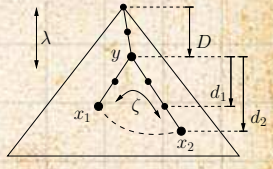
February, 1997:

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 → 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”

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References



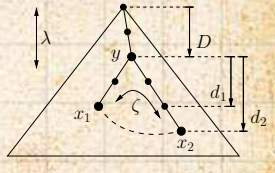
February, 1997:

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 → 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”

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References



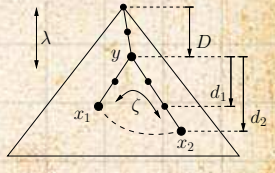
February, 1997:

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

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”



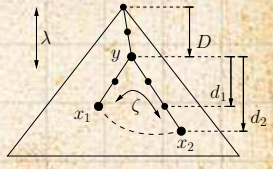
February, 1997:

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

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”



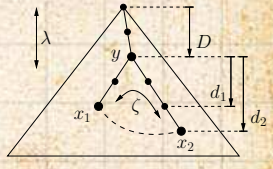
February, 1997:

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”

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References



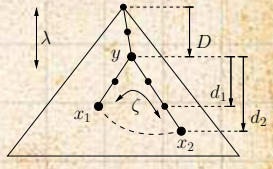
February, 1997:

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

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”



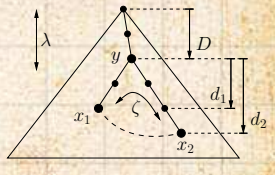
February, 1997:

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

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”

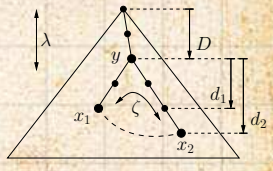


February, 1997:

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

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. separation by

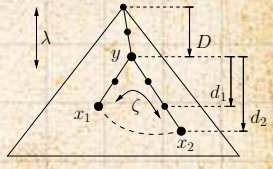


February, 1997:

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

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. separation of

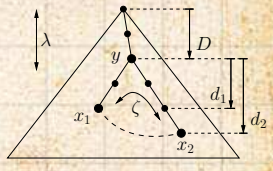


February, 1997:

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

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. separation by

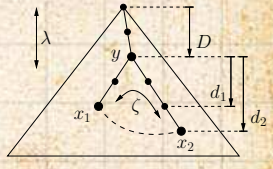


February, 1997:

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

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

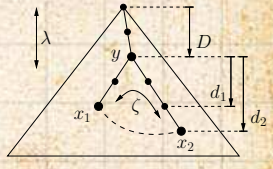


February, 1997:

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

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

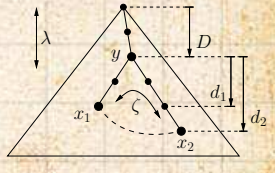


February, 1997:

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

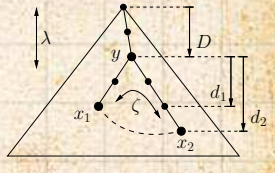
Some details:

- 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



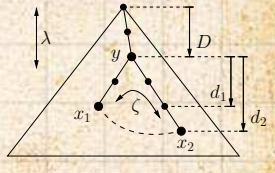
Some things fall apart:

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References



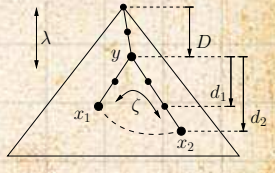
The UNIVERSITY of VERMONT

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References



Rebirth:

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References



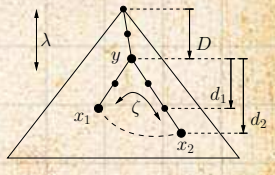
Outline

Overview
- Toyota
- Ambiguous problems
- Models of organizations:

Modelification
- Goals
- Model
- Testing
- Results

Conclusion

References



Motivation

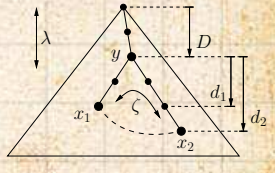
Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

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



Motivation

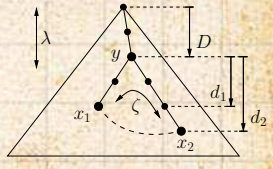
Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

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



Motivation

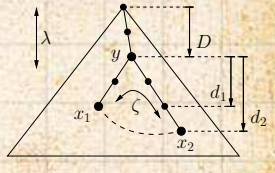
Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

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



Motivation

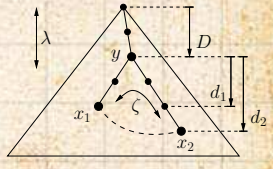
Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

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



Motivation

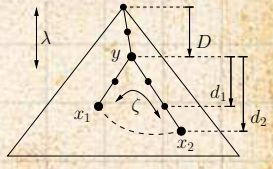
Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

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



Motivation

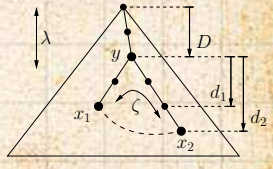
Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

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



Motivation

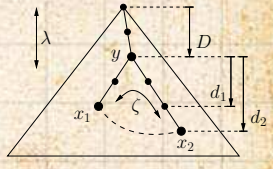
Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

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



Motivation

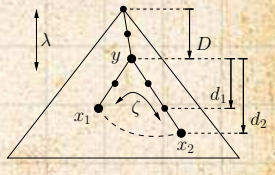
Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

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

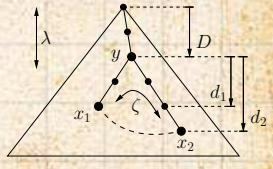


Motivation

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

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?

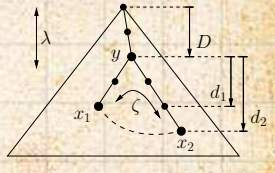


Motivation

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

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?

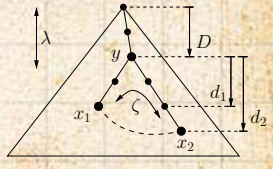


Motivation

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

Ambiguity:

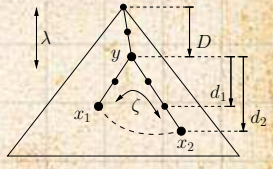
- Question much less answer is not well understood.
- Back and forth search process rephrases question.
- Leads to iterative process of query reformulation.
- Ambiguous tasks are inherently not decomposable.
- How do individuals collectively work on an ambiguous organization-scale problem?
- How do we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



Motivation

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?

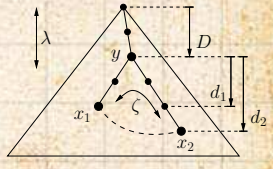


Motivation

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

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?

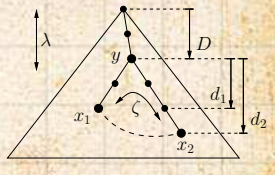


Motivation

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

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:

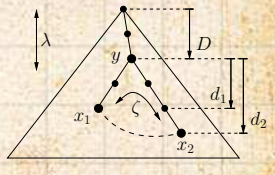
Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

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.



Let's modelify:

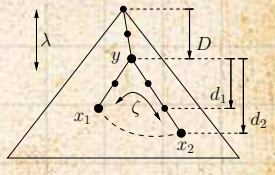
Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

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.



Let's modelify:

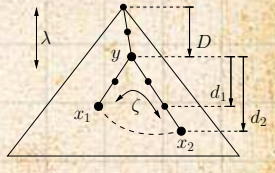
Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

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.



Let's modelify:

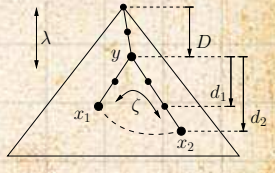
Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

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.



Let's modelify:

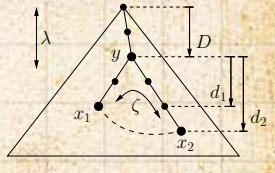
Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

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.



Let's modelify:

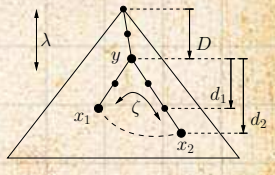
Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

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.



Let's modelify:

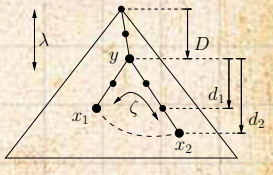
Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

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.



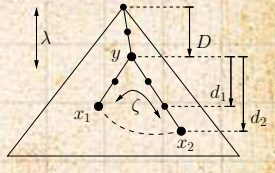
Outline

Overview
- Toyota
- Ambiguous problems
- Models of organizations:

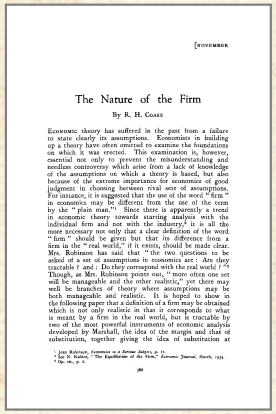
Modelification
- Goals
- Model
- Testing
- Results

Conclusion

References



Why organizations exist:



[NOVEMBER

The Nature of the Firm

By R. H. COASE

Economic theory has suffered in the past from a failure to state clearly its assumptions. Economists in building up a theory have often omitted to examine the foundations on which it was erected. This examination is, however, essential not only to prevent the misunderstanding and needless controversy which arise from a lack of knowledge of the assumptions on which a theory is based, but also because of the extreme importance for economics of good judgment in choosing between rival sets of assumptions. For instance, it is suggested that the use of the word "firm" in economics may be different from the use of the term by the "plain man."[1] Since there is apparently a trend in economic theory towards starting analysis with the individual firm and not with the industry,[2] it is all the more necessary not only that a clear definition of the word "firm" should be given but that its difference from a firm in the "real world," if it exists, should be made clear. Mrs. Robinson has said that "the two questions to be asked of a set of assumptions in economics are: Are they tractable? and: Do they correspond with the real world?"[3] Though, as Mrs. Robinson points out, "more often one set will be manageable and the other realistic," yet there may well be branches of theory where assumptions may be both manageable and realistic. It is hoped to show in the following paper that a definition of a firm may be obtained which is not only realistic in that it corresponds to what is meant by a firm in the real world, but is tractable by two of the most powerful instruments of economic analysis developed by Marshall, the idea of the margin and that of substitution, together giving the idea of substitution at

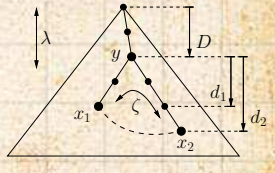
[1] Joan Robinson, *Economics is a Serious Subject*, p. 17.
[2] See N. Kaldor, "The Equilibrium of the Firm," *Economic Journal*, March, 1934.
[3] Op. cit., p. 6.

386

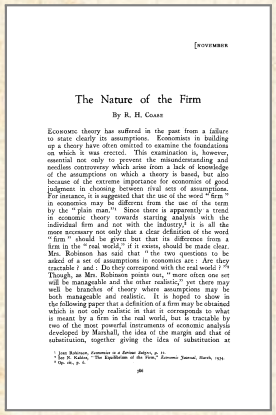
"The Nature of the Firm"
Ronald H. Coase,
Economica, **New Series, 4**, 386–405, 1937. [1]

- Notion of Transaction Costs.
- Were efficient for individuals to cooperate outside of the market.
- Coase had a solid career.

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References



Why organizations exist:



[NOVEMBER

The Nature of the Firm

By R. H. COASE

Economic theory has suffered in the past from a failure to state clearly its assumptions. Economists in building up a theory have often omitted to examine the foundations on which it was erected. This examination is, however, essential not only to prevent the misunderstanding and needless controversy which arise from a lack of knowledge of the assumptions on which a theory is based, but also because of the extreme importance for economics of good judgment in choosing between rival sets of assumptions. For instance, it is suggested that the use of the word "firm" in economics may be different from the use of the term by the "plain man."[1] Since there is apparently a trend in economic theory towards starting analysis with the individual firm and not with the industry,[2] it is all the more necessary not only that a clear definition of the word "firm" should be given but that its difference from a firm in the "real world," if it exists, should be made clear. Mrs. Robinson has said that "the two questions to be asked of a set of assumptions in economics are: Are they tractable? and: Do they correspond with the real world?"[3] Though, as Mrs. Robinson points out, "more often one set will be manageable and the other realistic," yet there may well be branches of theory where assumptions may be both manageable and realistic. It is hoped to show in the following paper that a definition of a firm may be obtained which is not only realistic in that it corresponds to what is meant by a firm in the real world, but is tractable by two of the most powerful instruments of economic analysis developed by Marshall, the idea of the margin and that of substitution, together giving the idea of substitution at

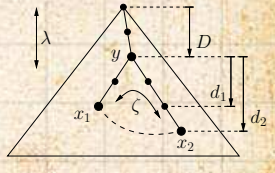
[1] Joan Robinson, *Economics is a Serious Subject*, p. 11.
[2] See H. Kahler, "The Equilibrium of the Firm," *Economic Journal*, March, 1934.
[3] *Op. cit.*, p. 6.

386

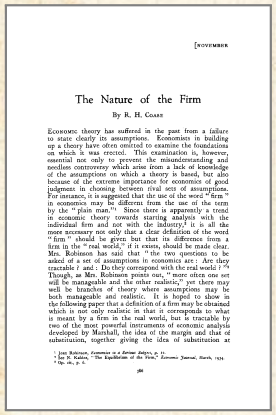
"The Nature of the Firm"
Ronald H. Coase,
Economica, **New Series, 4**, 386–405, 1937. [1]

- Notion of Transaction Costs.
- More efficient for individuals to cooperate outside of the market.
- Coase had a solid career.

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References



Why organizations exist:



[NOVEMBER

The Nature of the Firm

By R. H. COASE

Economic theory has suffered in the past from a failure to state clearly its assumptions. Economists in building up a theory have often omitted to examine the foundations on which it was erected. This examination is, however, essential not only to prevent the misunderstanding and needless controversy which arise from a lack of knowledge of the assumptions on which a theory is based, but also because of the extreme importance for economics of good judgment in choosing between rival sets of assumptions. For instance, it is suggested that the use of the word "firm" in economics may be different from the use of the term by the "plain man."[1] Since there is apparently a trend in economic theory towards starting analysis with the individual firm and not with the industry,[2] it is all the more necessary not only that a clear definition of the word "firm" should be given but that its difference from a firm in the "real world," if it exists, should be made clear. Mrs. Robinson has said that "the two questions to be asked of a set of assumptions in economics are: Are they tractable? and: Do they correspond with the real world?"[3] Though, as Mrs. Robinson points out, "more often one set will be manageable and the other realistic," yet there may well be branches of theory where assumptions may be both manageable and realistic. It is hoped to show in the following paper that a definition of a firm may be obtained which is not only realistic in that it corresponds to what is meant by a firm in the real world, but is tractable by two of the most powerful instruments of economic analysis developed by Marshall, the idea of the margin and that of substitution, together giving the idea of substitution at

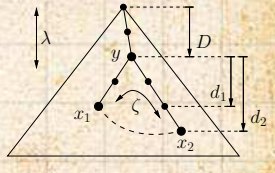
[1] Joan Robinson, *Economics is a Serious Subject*, p. 11.
[2] See H. Kahler, "The Equilibrium of the Firm," *Economic Journal*, March, 1934.
[3] *Op. cit.*, p. 8.

386

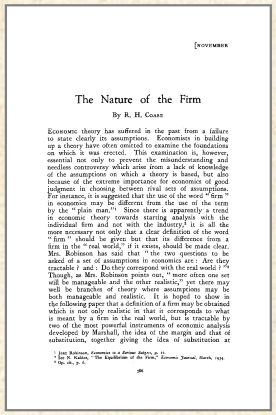
"The Nature of the Firm"
Ronald H. Coase,
Economica, **New Series, 4**, 386–405, 1937. [1]

- Notion of Transaction Costs.
- More efficient for individuals to cooperate outside of the market.
- Coase had a solid career.

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References



Why organizations exist:



[NOVEMBER

The Nature of the Firm

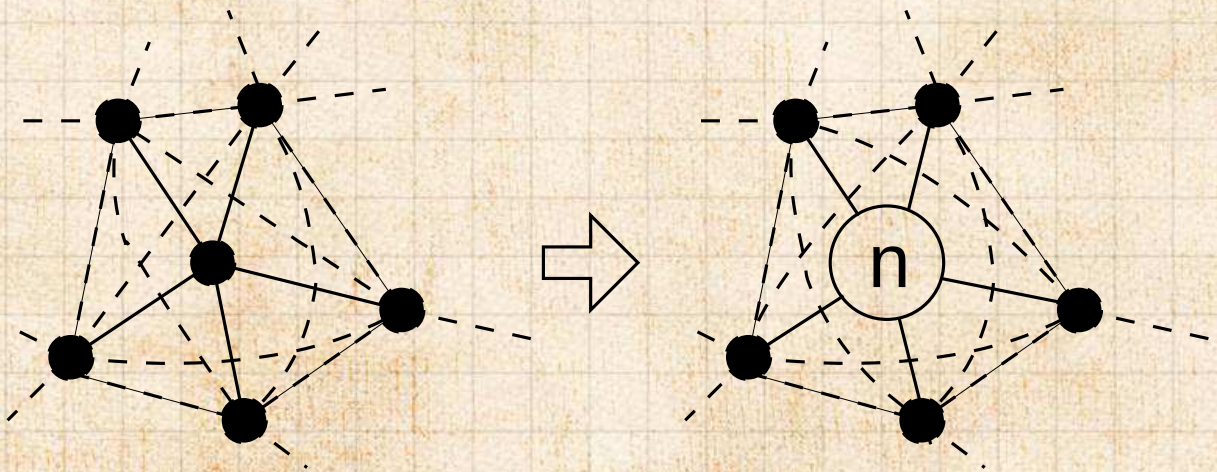
By R. H. COASE

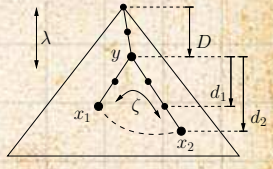
Economic theory has suffered in the past from a failure to state clearly its assumptions. Economists in building up a theory have often omitted to examine the foundations on which it was erected. This examination is, however, essential not only to prevent the misunderstanding and needless controversy which arise from a lack of knowledge of the assumptions on which a theory is based, but also because of the extreme importance for economics of good judgment in choosing between rival sets of assumptions. For instance, it is suggested that the use of the word "firm" in economics may be different from the use of the term by the "plain man."[1] Since there is apparently a trend in economic theory towards starting analysis with the individual firm and not with the industry,[2] it is all the more necessary not only that a clear definition of the word "firm" should be given but that its difference from a firm in the "real world," if it exists, should be made clear. Mrs. Robinson has said that "the two questions to be asked of a set of assumptions in economics are: Are they tractable? and: Do they correspond with the real world?"[3] Though, as Mrs. Robinson points out, "more often one set will be manageable and the other realistic," yet there may well be branches of theory where assumptions may be both manageable and realistic. It is hoped to show in the following paper that a definition of a firm may be obtained which is not only realistic in that it corresponds to what is meant by a firm in the real world, but is tractable by two of the most powerful instruments of economic analysis developed by Marshall, the idea of the margin and that of substitution, together giving the idea of substitution at

[1] Joan Robinson, *Economics is a Serious Subject*, p. 17.
[2] See H. Kaldor, "The Equilibrium of the Firm," *Economic Journal*, March, 1934.
[3] *Op. cit.*, p. 1.

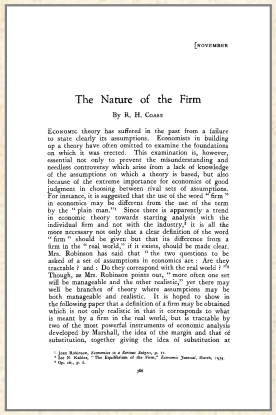
"The Nature of the Firm"
Ronald H. Coase,
Economica, **New Series, 4**, 386–405, 1937. [1]

- Notion of Transaction Costs.
- More efficient for individuals to cooperate outside of the market.





Why organizations exist:



[NOVEMBER

The Nature of the Firm

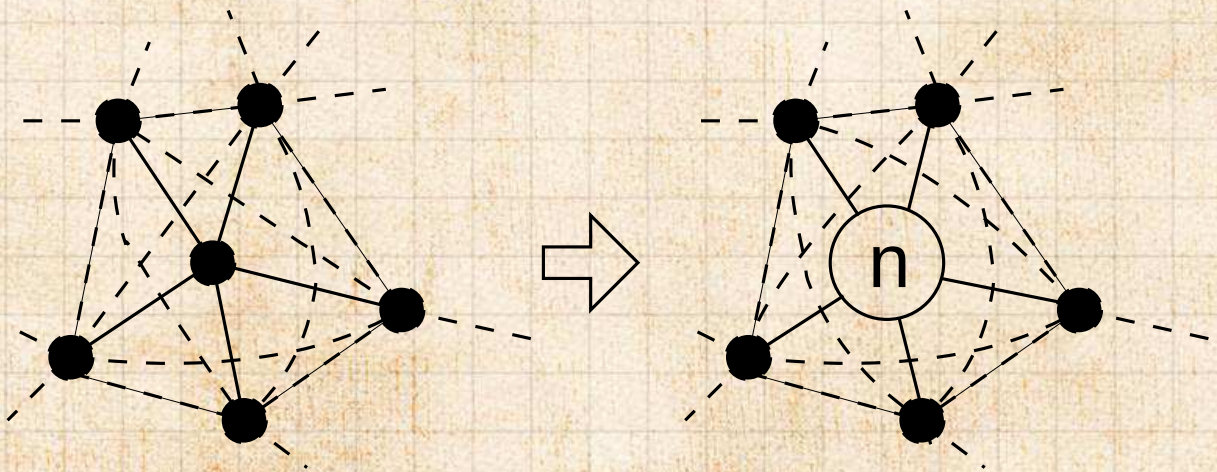
By R. H. COASE

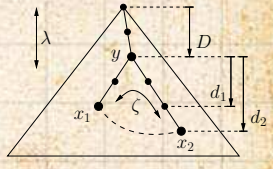
Economic theory has suffered in the past from a failure to state clearly its assumptions. Economists in building up a theory have often omitted to examine the foundations on which it was erected. This examination is, however, essential not only to prevent the misunderstanding and needless controversy which arise from a lack of knowledge of the assumptions on which a theory is based, but also because of the extreme importance for economics of good judgment in choosing between rival sets of assumptions. For instance, it is suggested that the use of the word "firm" in economics may be different from the use of the term by the "plain man."[1] Since there is apparently a trend in economic theory towards starting analysis with the individual firm and not with the industry,[2] it is all the more necessary not only that a clear definition of the word "firm" should be given but that its difference from a firm in the "real world," if it exists, should be made clear. Mrs. Robinson has said that "the two questions to be asked of a set of assumptions in economics are: Are they tractable? and: Do they correspond with the real world?"[3] Though, as Mrs. Robinson points out, "more often one set will be manageable and the other realistic," yet there may well be branches of theory where assumptions may be both manageable and realistic. It is hoped to show in the following paper that a definition of a firm may be obtained which is not only realistic in that it corresponds to what is meant by a firm in the real world, but is tractable by two of the most powerful instruments of economic analysis developed by Marshall, the idea of the margin and that of substitution, together giving the idea of substitution at

[1] Joan Robinson, *Economics is a Serious Subject*, p. 17.
[2] See H. Kaldor, "The Equilibrium of the Firm," *Economic Journal*, March, 1934.
[3] *Op. cit.*, p. 1.

"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.





Real organizations—Extremes

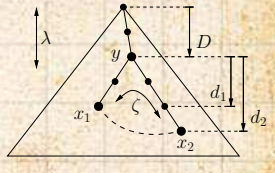
Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

Hierarchy:

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

Market:

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



Real organizations—Extremes

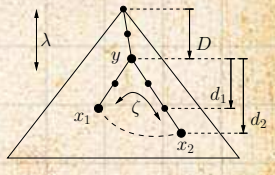
Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

Hierarchy:

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

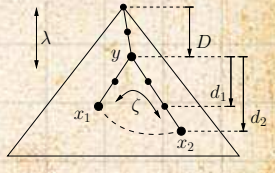
Market:

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



Organizations as efficient hierarchies

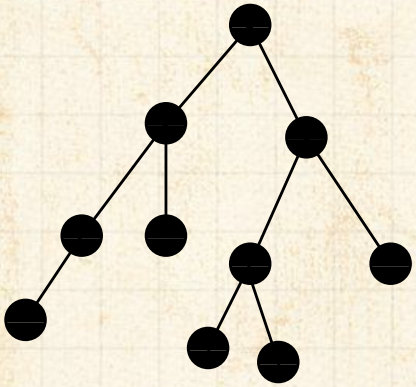
- Economics: Organizations ≡ Hierarchies.
- e.g., Radner (1993) [5], Van Zandt (1998) [7]
- Hierarchies performing associative operations:

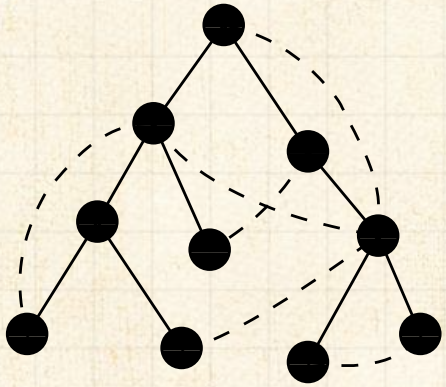


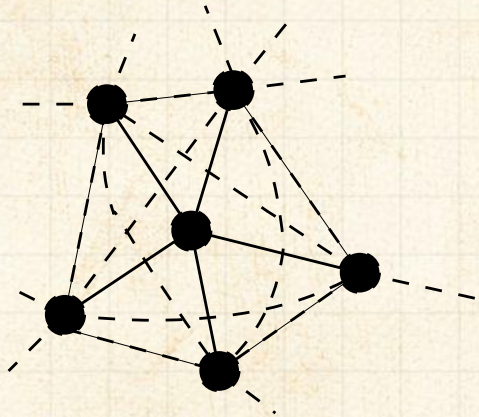
Real organizations...

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

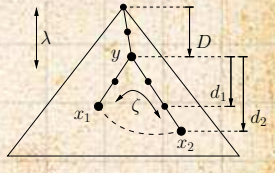
But real, complex organizations are in the middle...







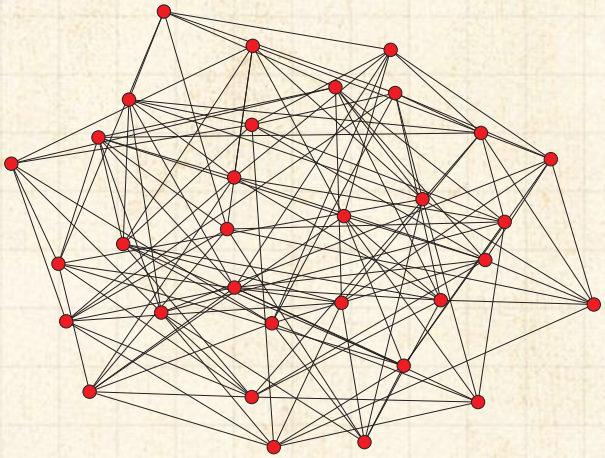
"Heterarchy"
David Stark,
The Biology of Business: Decoding the Natural Laws of the Enterprise., **New Series, 4**, 153–, 1999. [6]

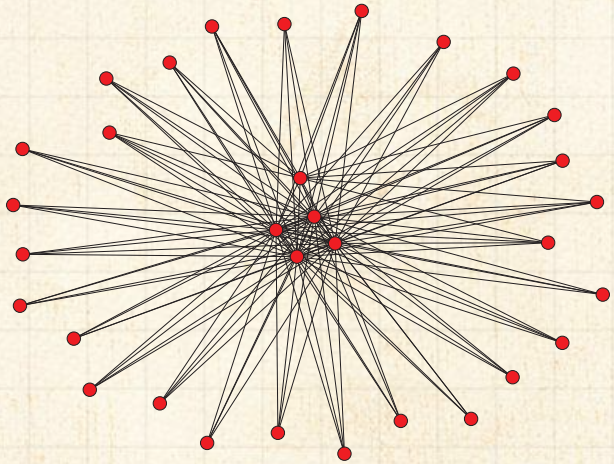


Optimal network topologies for local search

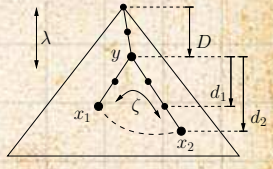
"Optimal network topologies for local search with congestion"

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





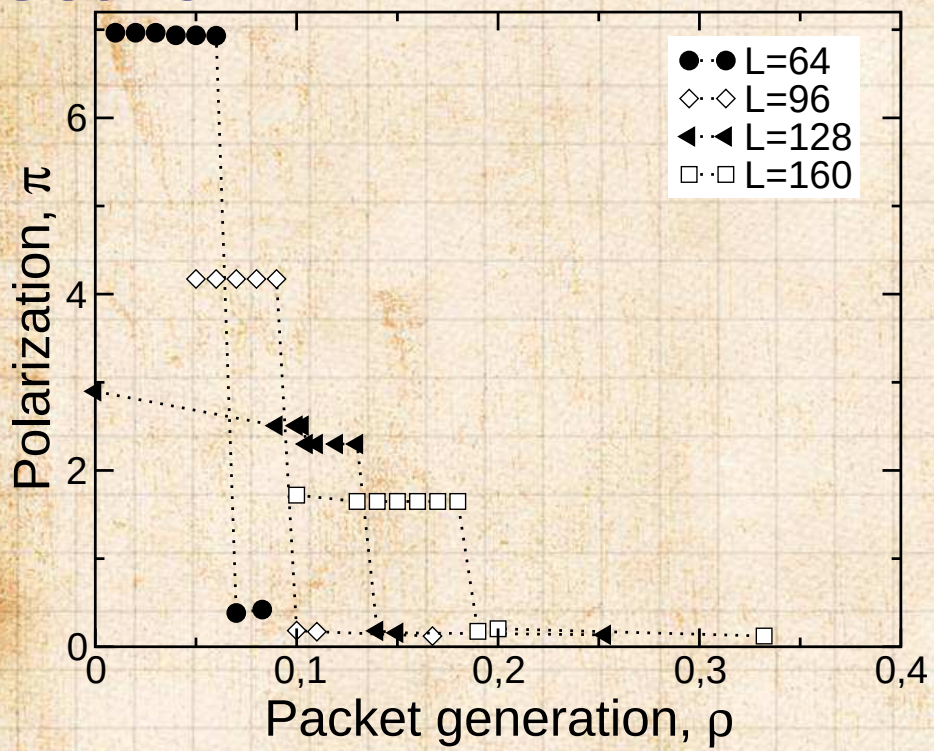
- Parallel search and congestion.
- Queueing and network collapse.
- Exploration of random search mechanisms.



Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

The UNIVERSITY of VERMONT

Optimal network topologies for local search

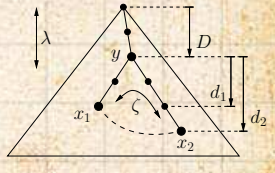


- Betweenness: β.
- Polarization:

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

- L = number of links.

- Goal: minimize average search time.
- Few searches $\Rightarrow$ hub-and-spoke network.
- Many searches $\Rightarrow$ decentralized network.
- Phase transition?



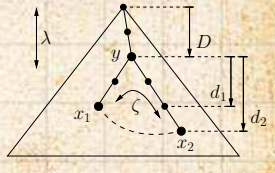
Outline

Overview
- Toyota
- Ambiguous problems
- Models of organizations:

Modelification
- Goals
- Model
- Testing
- Results

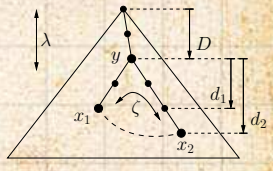
Conclusion

References



Desirable organizational qualities:

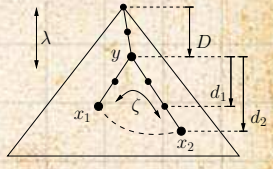
1. Low cost (requiring few links).
2. Scalability.
3. Ease of construction—existence is plausible.
4. Searchability.
5. ‘Ultra-robustness’:
   - Congestion robustness (resilience to failure due to information exchange).
   - Connectivity robustness (recoverability in the event of failure).



Desirable organizational qualities:

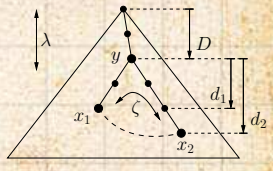
1. Low cost (requiring few links).
2. Scalability.
3. Ease of construction—existence is plausible.
4. Searchability.
5. 'Ultra-robustness':
   I. Congestion robustness (Resilience to failure due to information exchange).
   II. Connectivity robustness (Recoverability in the event of failure).

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References



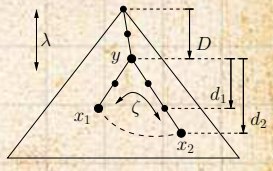
Desirable organizational qualities:

1. Low cost (requiring few links).
2. Scalability.
3. Ease of construction—existence is plausible.
4. Searchability.
5. ‘Ultra-robustness’:
   - Congestion robustness
   - (Resilience to failure due to information exchange)
   - Connectivity robustness
   - (Recoverability in the event of failure)



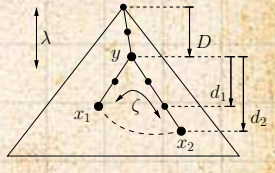
Desirable organizational qualities:

1. Low cost (requiring few links).
2. Scalability.
3. Ease of construction—existence is plausible.
4. Searchability.
5. ‘Ultra-robustness’:
   - Congestion robustness
   - (Resilience to failure due to information exchange)
   - Connectivity robustness
   - (Recoverability in the event of failure)



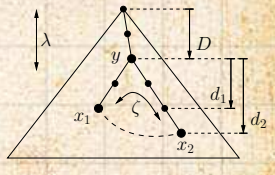
Desirable organizational qualities:

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).



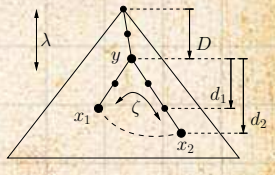
Desirable organizational qualities:

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).



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).

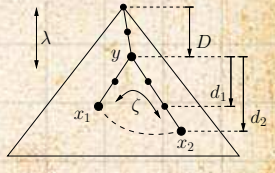


Searchability

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

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]



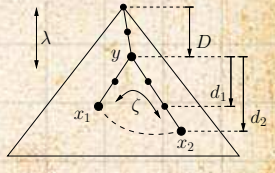
Outline

Overview
- Toyota
- Ambiguous problems
- Models of organizations:

Modelification
- Goals
- Model
- Testing
- Results

Conclusion

References



Information exchange and the robustness of organizational networks

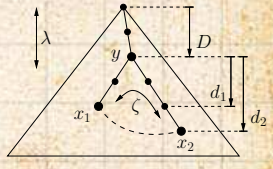
"Information exchange and the robustness of organizational networks"

Dodds, Watts, and Sabel, Proc. Natl. Acad. Sci., **100**, 12516–12521, 2003. [2]

Edited by Harrison White

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



Information exchange and the robustness of organizational networks

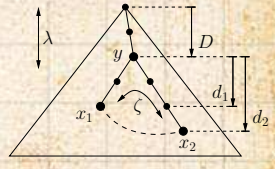
"Information exchange and the robustness of organizational networks"
Dodds, Watts, and Sabel,
Proc. Natl. Acad. Sci., **100**, 12516–12521, 2003. [2]

Edited by Harrison White

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

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References



Information exchange and the robustness of organizational networks

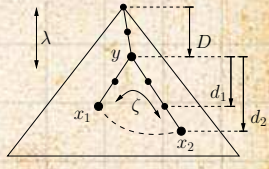
"Information exchange and the robustness of organizational networks"
Dodds, Watts, and Sabel,
Proc. Natl. Acad. Sci., **100**, 12516–12521, 2003. [2]

Edited by Harrison White

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

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References



Information exchange and the robustness of organizational networks

"Information exchange and the robustness of organizational networks"
Dodds, Watts, and Sabel,
Proc. Natl. Acad. Sci., **100**, 12516–12521, 2003. [2]

Edited by Harrison White

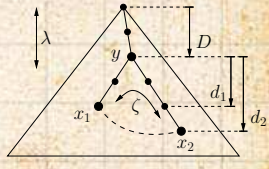
Formal organizational structure:

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



Information exchange and the robustness of organizational networks

"Information exchange and the robustness of organizational networks"
Dodds, Watts, and Sabel,
Proc. Natl. Acad. Sci., **100**, 12516–12521, 2003. [2]

Edited by Harrison White

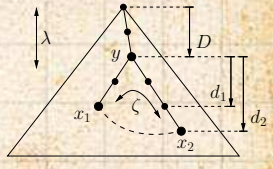
Formal organizational structure:

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



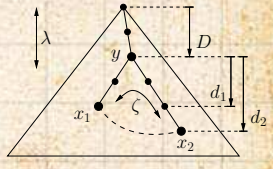
Information exchange and the robustness of organizational networks

"Information exchange and the robustness of organizational networks"
Dodds, Watts, and Sabel,
Proc. Natl. Acad. Sci., **100**, 12516–12521, 2003. [2]

- Edited by Harrison White

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



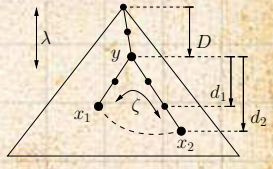
Information exchange and the robustness of organizational networks

"Information exchange and the robustness of organizational networks"
Dodds, Watts, and Sabel,
Proc. Natl. Acad. Sci., **100**, 12516–12521, 2003. [2]

- Edited by Harrison White

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



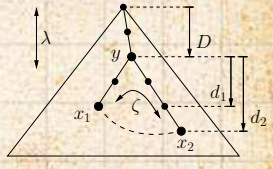
Information exchange and the robustness of organizational networks

"Information exchange and the robustness of organizational networks"
Dodds, Watts, and Sabel,
Proc. Natl. Acad. Sci., **100**, 12516–12521, 2003. [2]

- Edited by Harrison White

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



Information exchange and the robustness of organizational networks

"Information exchange and the robustness of organizational networks"
Dodds, Watts, and Sabel,
Proc. Natl. Acad. Sci., **100**, 12516–12521, 2003. [2]

Edited by Harrison White

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

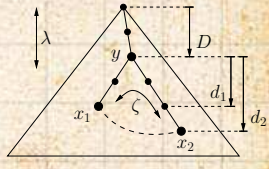
COcoNuTS

Overview
Toyota
Ambiguous problems
Models of organizations:

Modelification
Goals
Model
Testing
Results

Conclusion

References



The University of Vermont

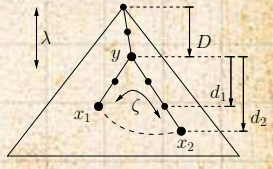
Information exchange and the robustness of organizational networks

"Information exchange and the robustness of organizational networks"
Dodds, Watts, and Sabel,
Proc. Natl. Acad. Sci., **100**, 12516–12521, 2003. [2]

- Edited by Harrison White

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



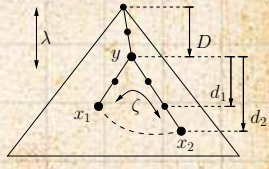
Information exchange and the robustness of organizational networks

"Information exchange and the robustness of organizational networks"
Dodds, Watts, and Sabel,
Proc. Natl. Acad. Sci., **100**, 12516–12521, 2003. [2]

- Edited by Harrison White

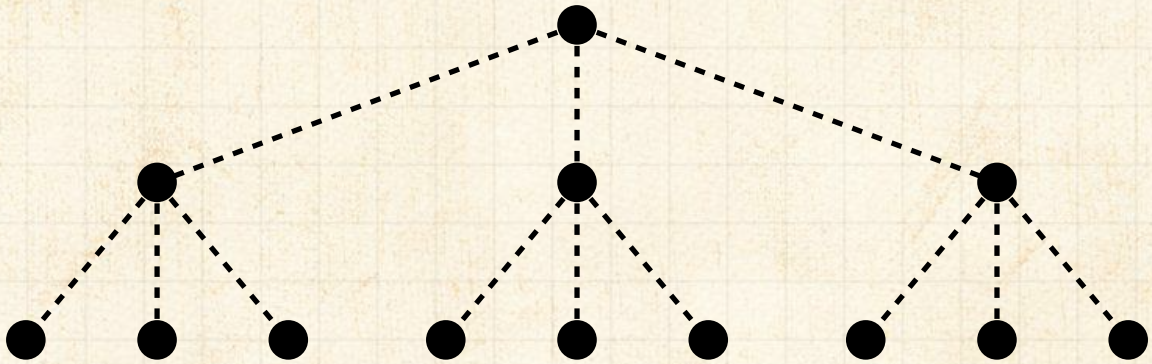
Formal organizational structure:

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

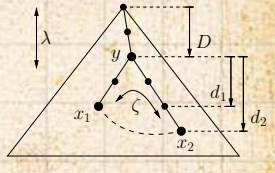


Model—underlying hierarchy

Model—formal structure:



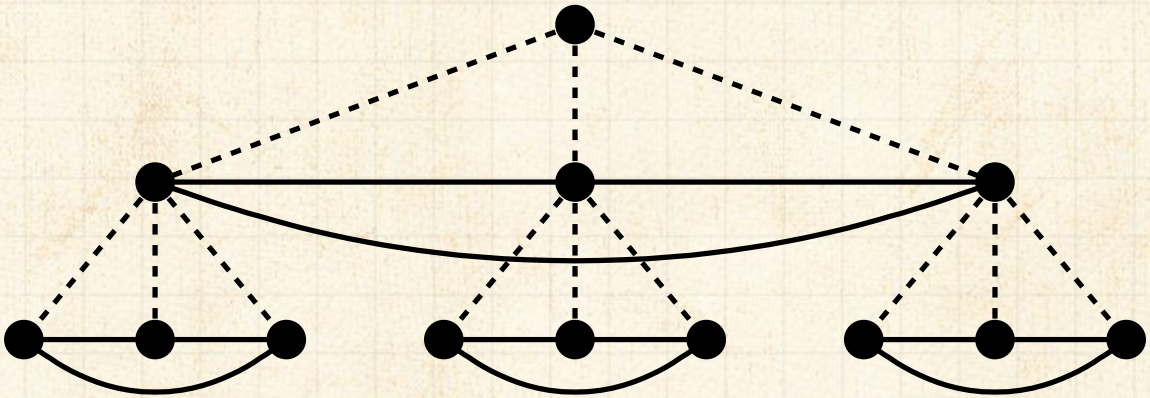
$$b = 3, \quad L = 3, \quad N = 13$$

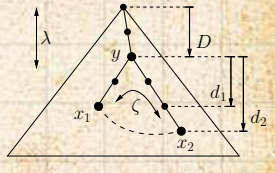


Model—addition of links

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

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

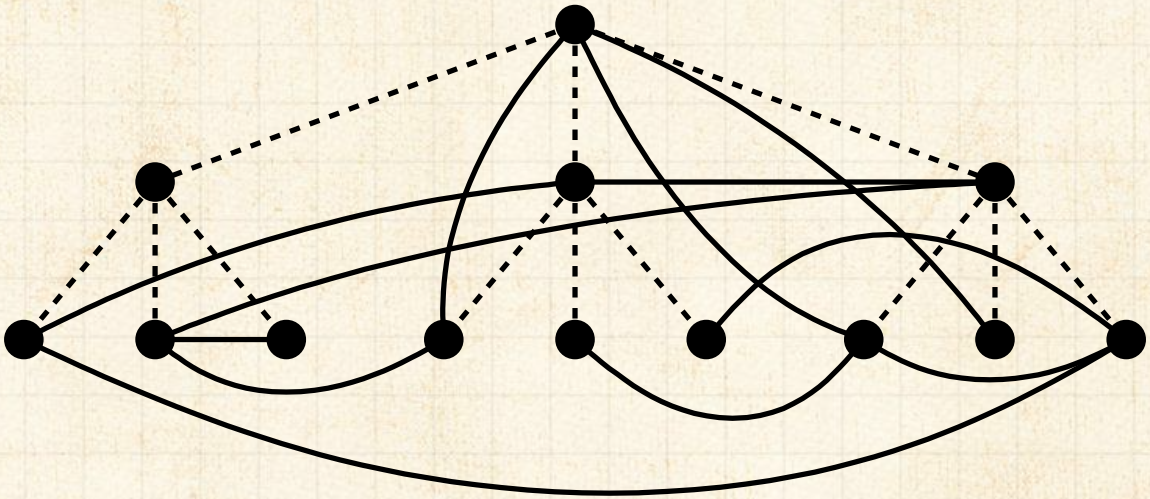


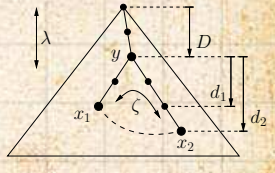


Model—addition of links

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

Random networks ($m = 12$):

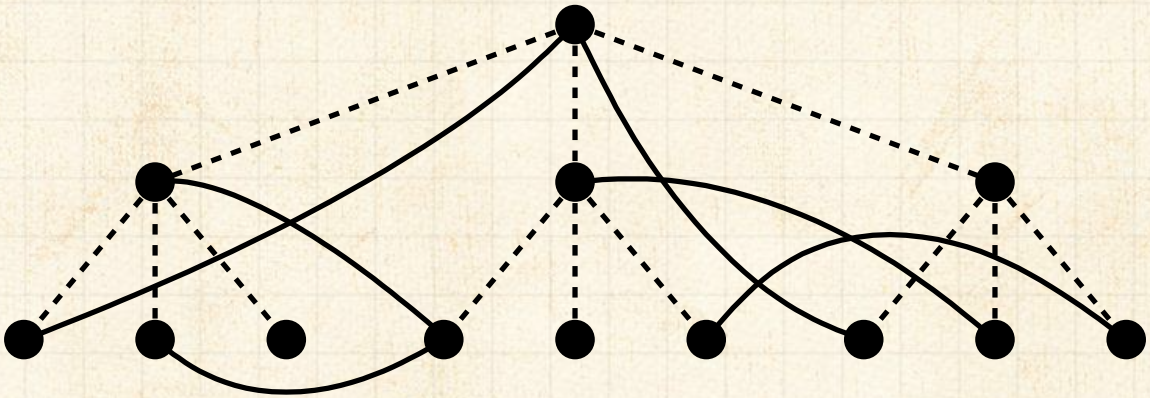


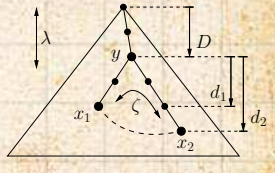


Model—addition of links

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

Random interdivisional networks ($m = 6$):

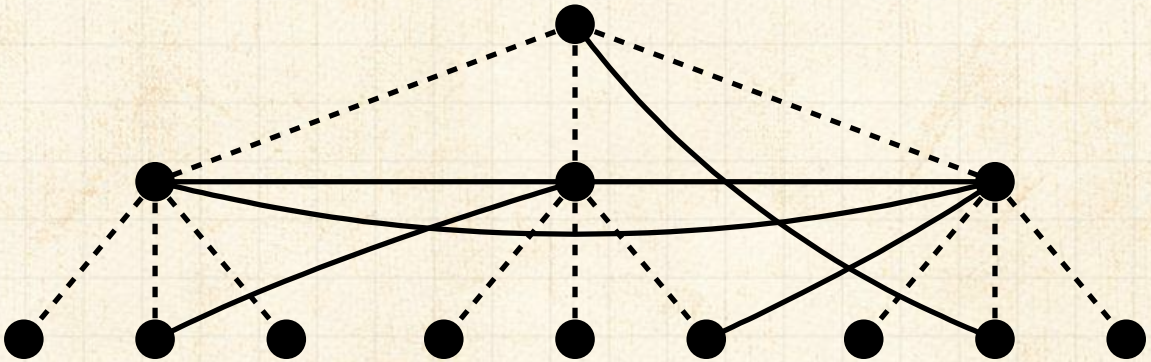


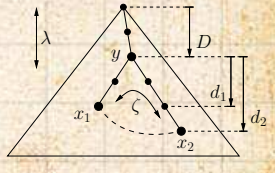


Model—addition of links

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

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

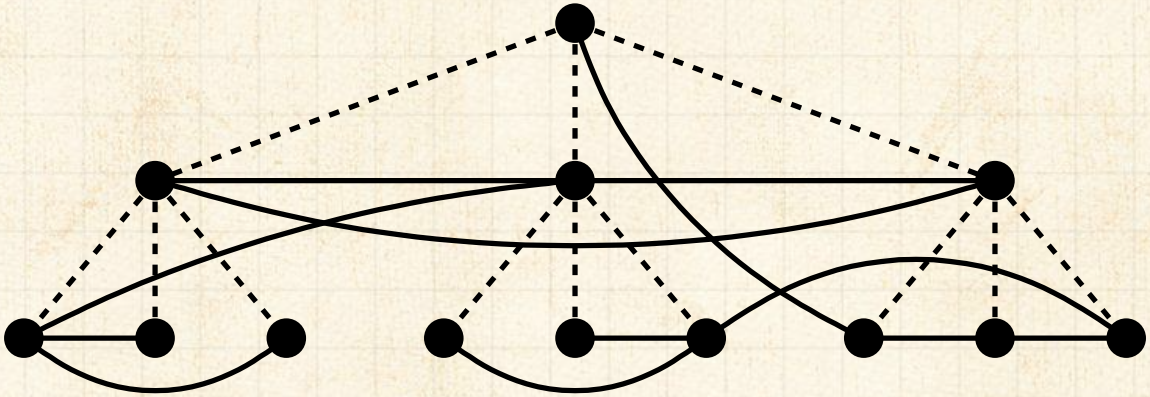


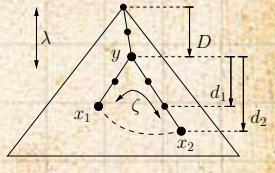


Model—addition of links

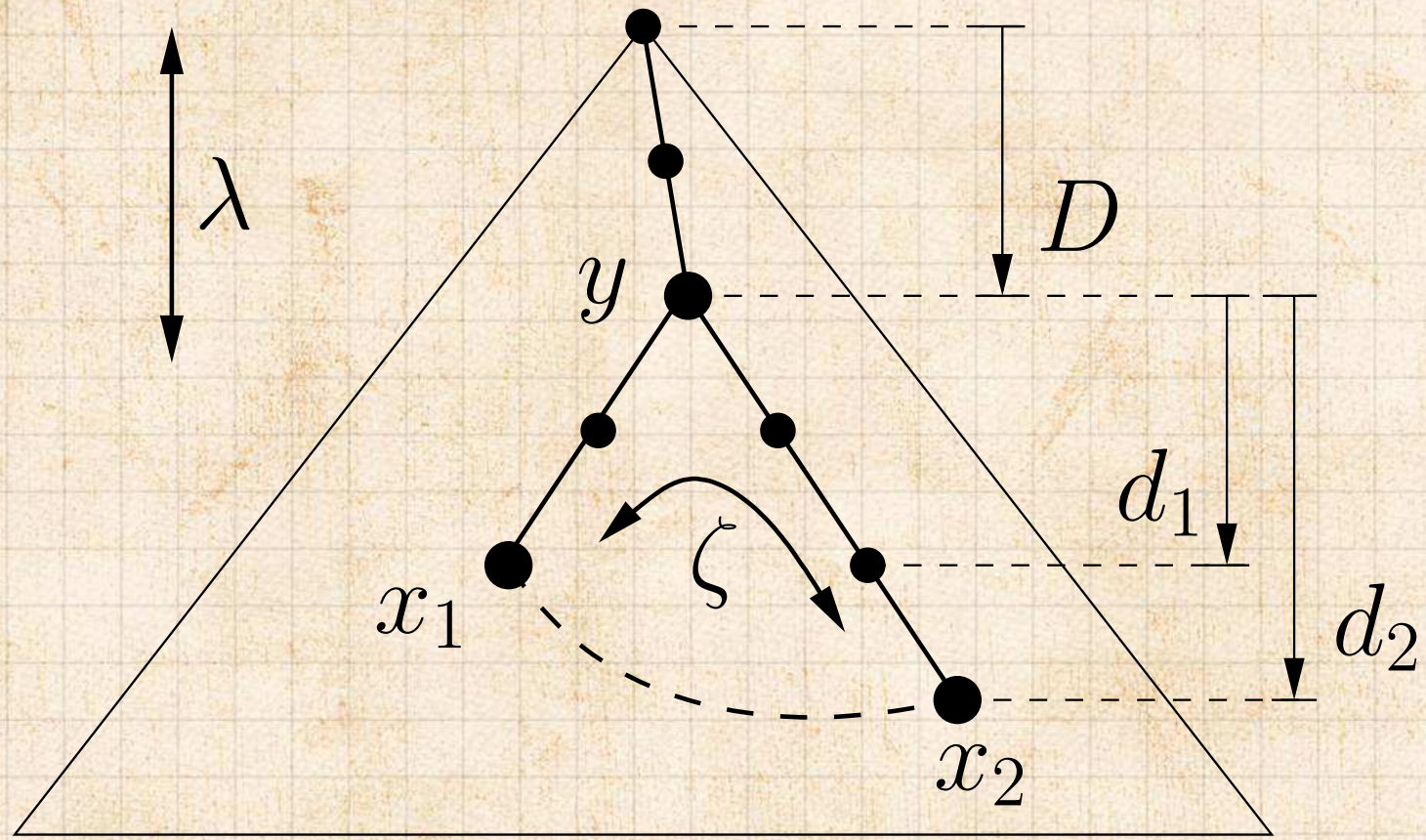
Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

Multiscale networks $(m = 12)$:

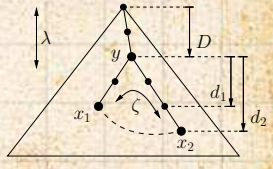




Model—construction



Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

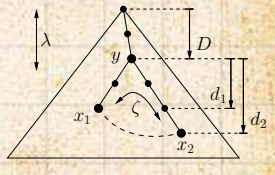


Model—construction

- 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

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

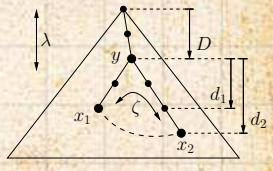
Requirements for $f(d_1, d_2)$:

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 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—construction

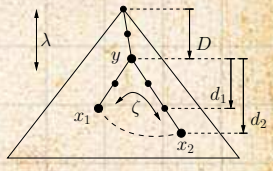
Requirements for $f(d_1, d_2)$:

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 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—construction

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

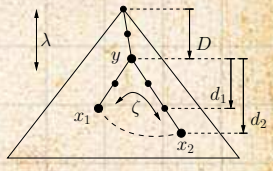
Requirements for $f(d_1, d_2)$:

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 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—construction

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

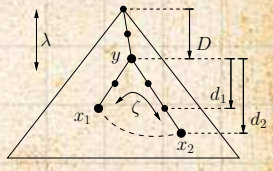
Requirements for $f(d_1, d_2)$:

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 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—construction

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

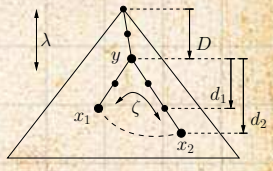
Requirements for $f(d_1, d_2)$:

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 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—construction

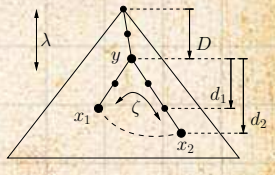
Requirements for $f(d_1, d_2)$:

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 maximized when $d_1 = d_2$.

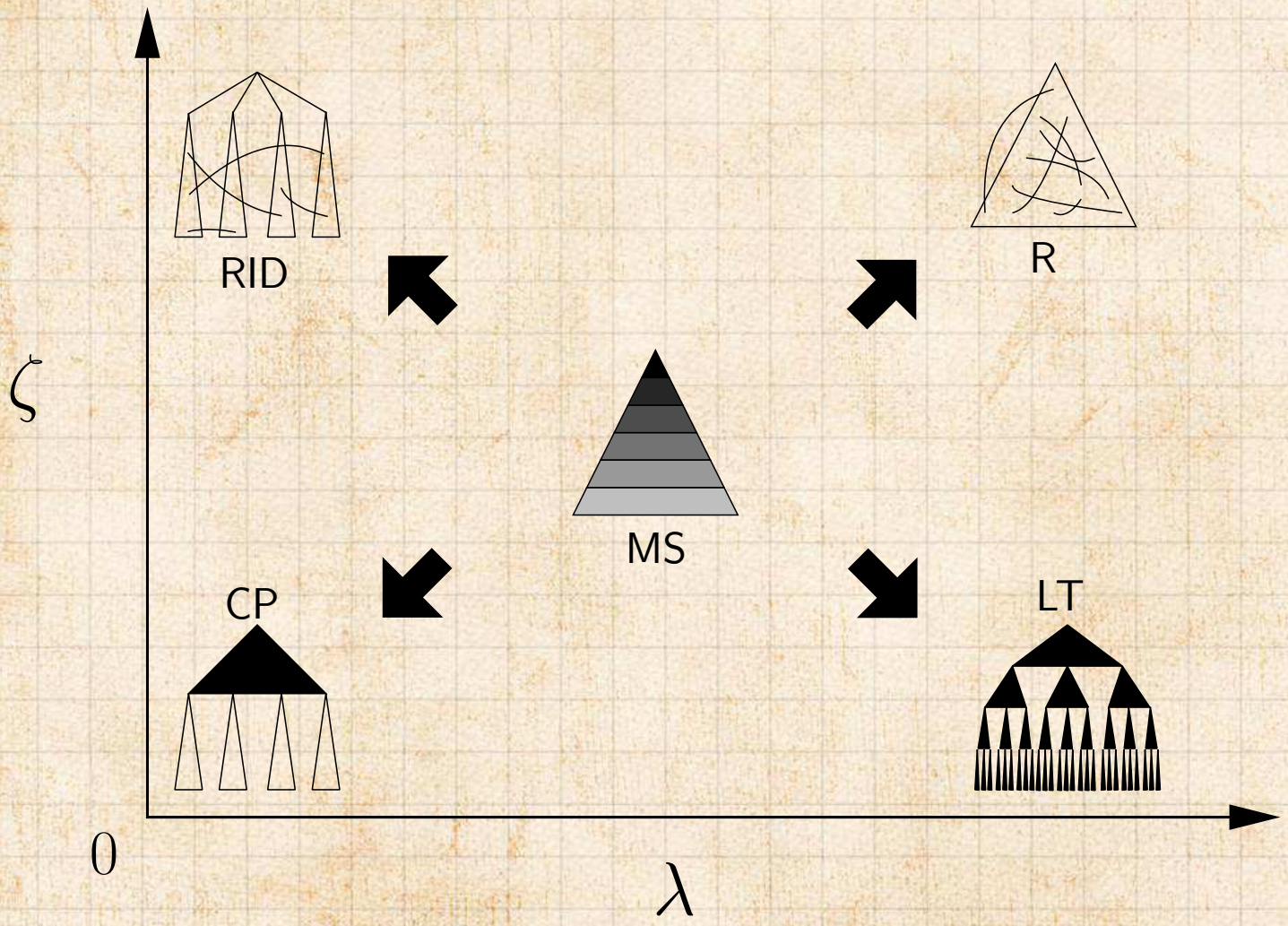
Simple function satisfying 1–4:

$$f(d_1, d_2) = (d_1^2 + d_2^2 - 2)^{1/2}$$

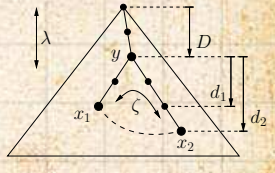
$$\Rightarrow P(y, x_1, x_2) \propto e^{-D/\lambda} e^{-(d_1^2+d_2^2-2)^{1/2}/\zeta}$$



Model—limiting cases



Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References



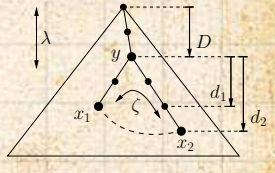
Outline

Overview
- Toyota
- Ambiguous problems
- Models of organizations:

Modelification
- Goals
- Model
- Testing
- Results

Conclusion

References

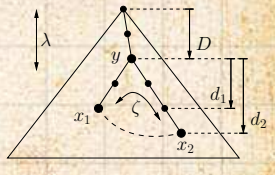


Message passing pattern

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

- Each of T time steps, each node generates a message with probability μ.
- Recipient of message chosen based on distance from sender.
- $$P(\text{recipient at distance } d) \propto e^{-d/\xi}.$$

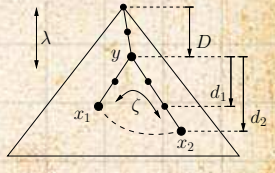
1. ξ = measure of uncertainty;
2. $\xi = 0$: local message passing;
3. $\xi = \infty$: random message passing.



Message passing pattern

- 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.

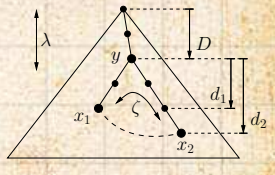


Message passing pattern

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

- Each of T time steps, each node generates a message with probability μ.
- Recipient of message chosen based on distance from sender.
- $$P(\text{recipient at distance } d) \propto e^{-d/\xi}.$$

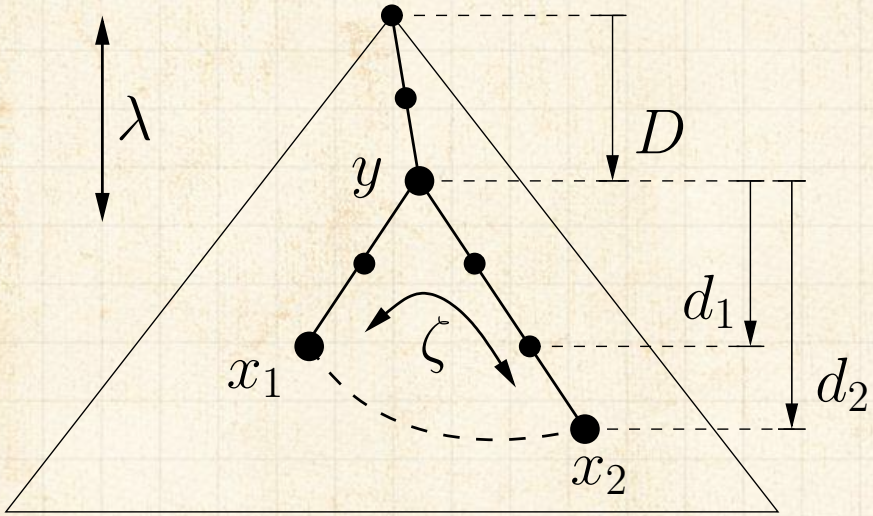
1. ξ = measure of uncertainty;
2. $\xi = 0$: local message passing;
3. $\xi = \infty$: random message passing.



Message passing pattern:

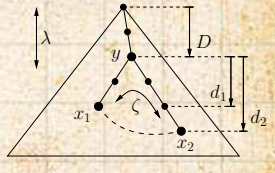
Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

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.

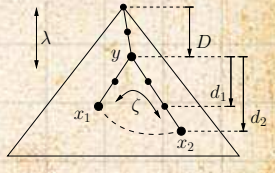


Message passing pattern

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

Simple message routing algorithm:

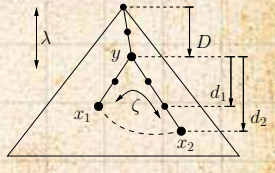
- Look ahead one step: always choose neighbor closest to recipient node.
- Pseudo-global knowledge:
  1. Nodes understand hierarchy.
  2. Nodes know only local informal ties.



Message passing pattern

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.

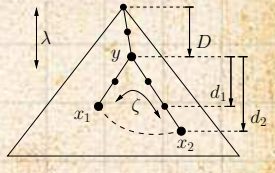


Message passing pattern

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

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.

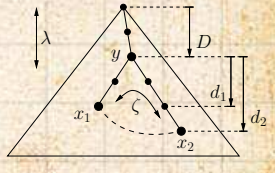


Message passing pattern

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

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.

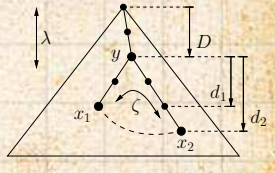


Message passing pattern

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

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.

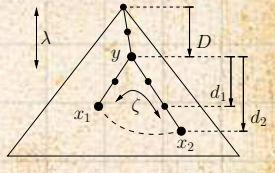


Message passing pattern

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

Interpretations:

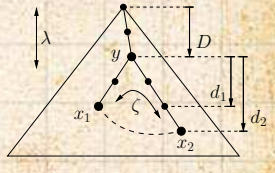
1. Sender knows specific recipient.
2. Sender requires certain kind of recipient.
3. Sender seeks specific information but recipient unknown.
4. Sender has a problem but information/recipient unknown.



Message passing pattern

Performance:

- Measure Congestion Centrality ρ_i, fraction of messages passing through node i.
- Similar to betweenness centrality.
- However: depends on
  1. Search strategy
  2. Task specification
- Congestion robustness comes from minimizing $\rho_{\max}$.

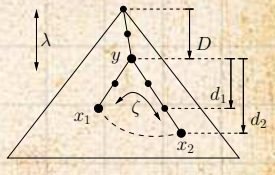


Message passing pattern

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

Performance:

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

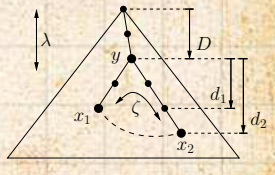


Message passing pattern

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

Performance:

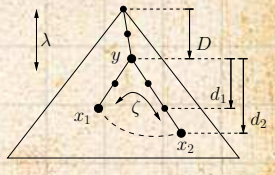
- Measure Congestion Centrality ρ_i, fraction of messages passing through node i.
- Similar to betweenness centrality.
- However: depends on
  1. Search algorithm;
  2. Task specification (μ, ξ).
- Congestion robustness comes from minimizing $\rho_{\max}$.



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;
  2. Task specification (μ, ξ).
- Congestion robustness comes from minimizing $\rho_{\max}$.

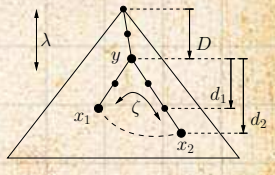


Message passing pattern

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

Performance:

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



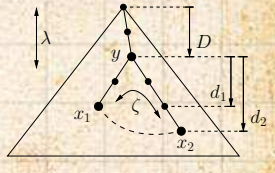
Outline

Overview
- Toyota
- Ambiguous problems
- Models of organizations:

Modelification
- Goals
- Model
- Testing
- Results

Conclusion

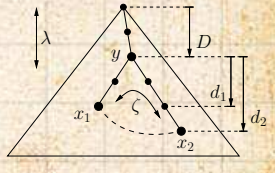
References



Performance testing:

Parameter settings (unless varying):

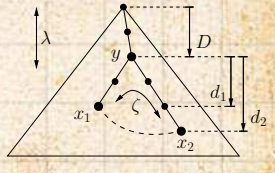
- Underlying hierarchy: $b = 5$, $L = 6$, $N = 3096$;
- Number of informal ties: $m = N$.
- Link addition algorithm: $\lambda = \zeta = 0.5$.
- Message passing: $\xi = 1$, $\mu = 10/N$, $T = 1000$.



Performance testing:

Parameter settings (unless varying):

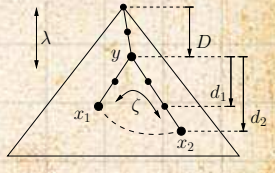
- Underlying hierarchy: $b = 5$, $L = 6$, $N = 3096$;
- Number of informal ties: $m = N$.
- Link addition algorithm: $\lambda = \zeta = 0.5$.
- Message passing: $\xi = 1$, $\mu = 10/N$, $T = 1000$.



Performance testing:

Parameter settings (unless varying):

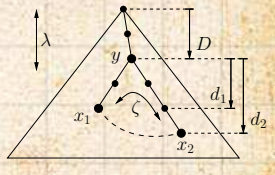
- Underlying hierarchy: $b = 5$, $L = 6$, $N = 3096$;
- Number of informal ties: $m = N$.
- Link addition algorithm: $\lambda = \zeta = 0.5$.
- Message passing: $\xi = 1$, $\mu = 10/N$, $T = 1000$.



Performance testing:

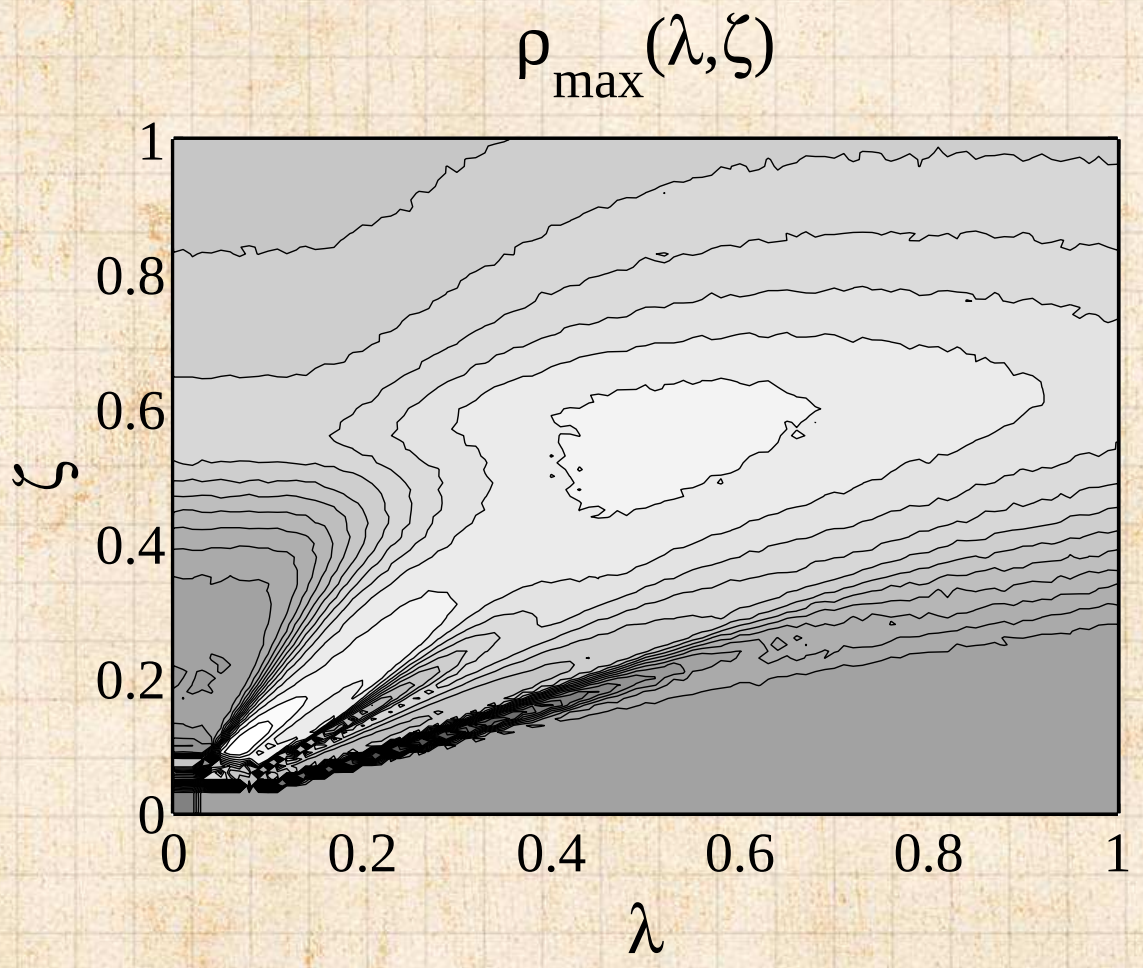
Parameter settings (unless varying):

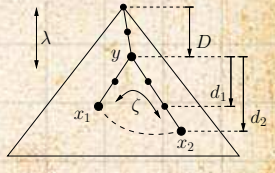
- Underlying hierarchy: $b = 5$, $L = 6$, $N = 3096$;
- Number of informal ties: $m = N$.
- Link addition algorithm: $\lambda = \zeta = 0.5$.
- Message passing: $\xi = 1$, $\mu = 10/N$, $T = 1000$.



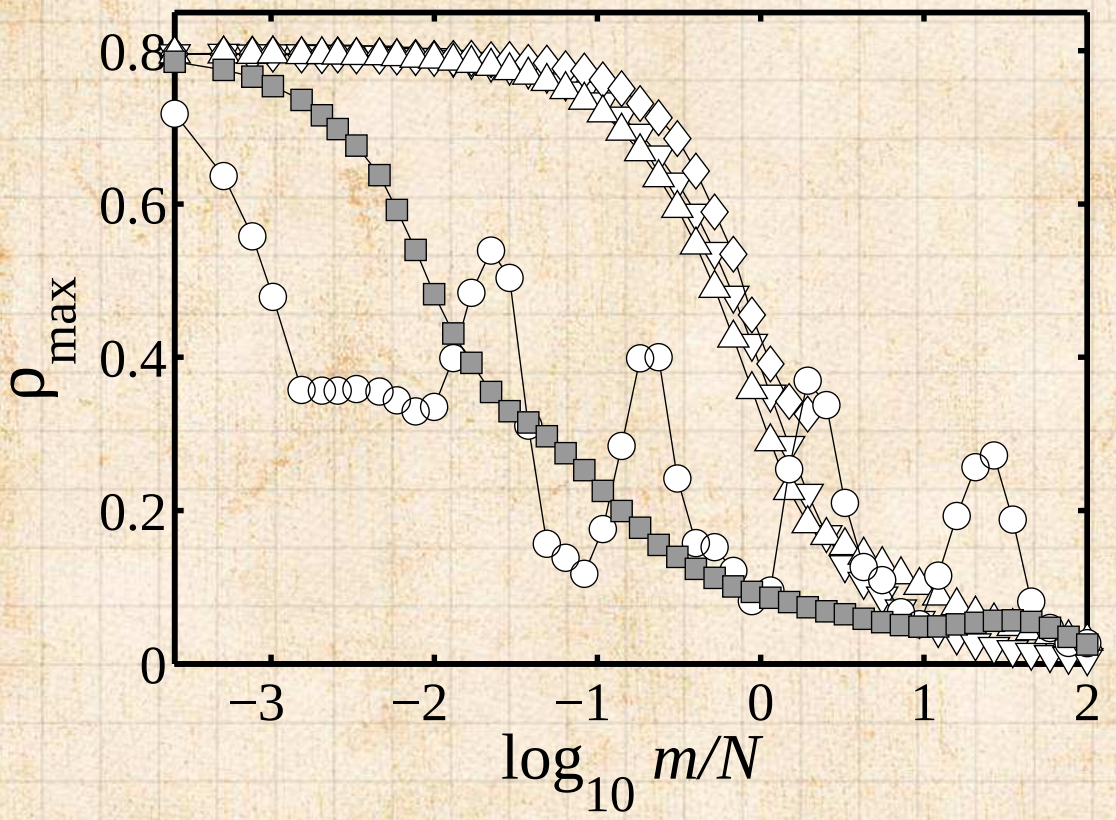
Results—congestion robustness

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References





Results—varying number of links added:



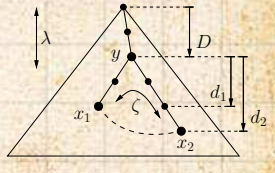
◇=TB

▽=R

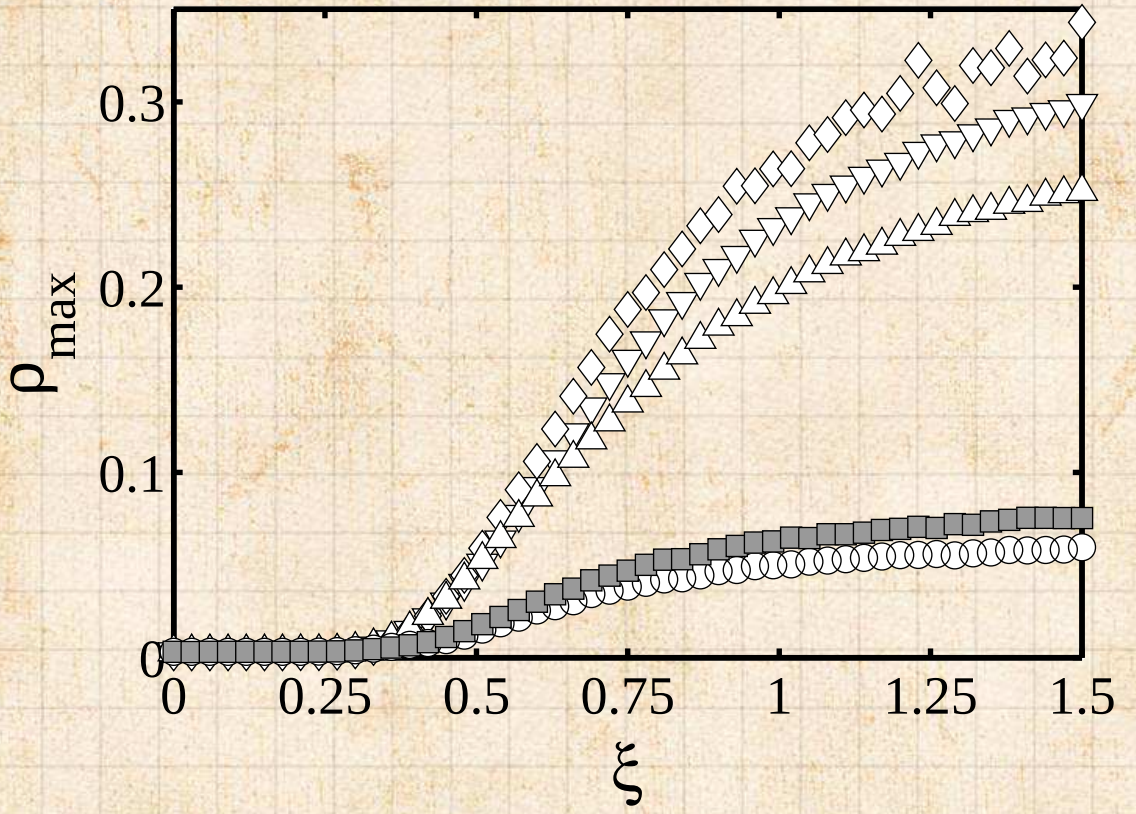
△=RID

○=CP

□=MS



Results—varying message passing pattern



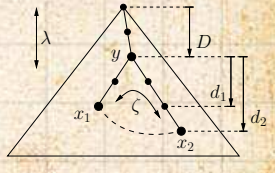
◇=TB

▽=R

△=RID

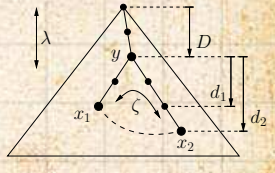
○=CP

□=MS



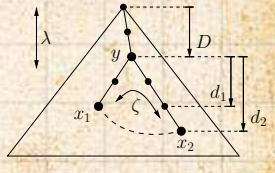
Results—Maximum firm size

- 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.



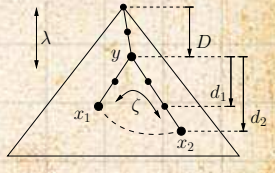
Results—Maximum firm size

- 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.



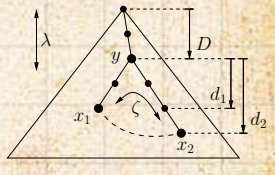
Results—Maximum firm size

- 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.

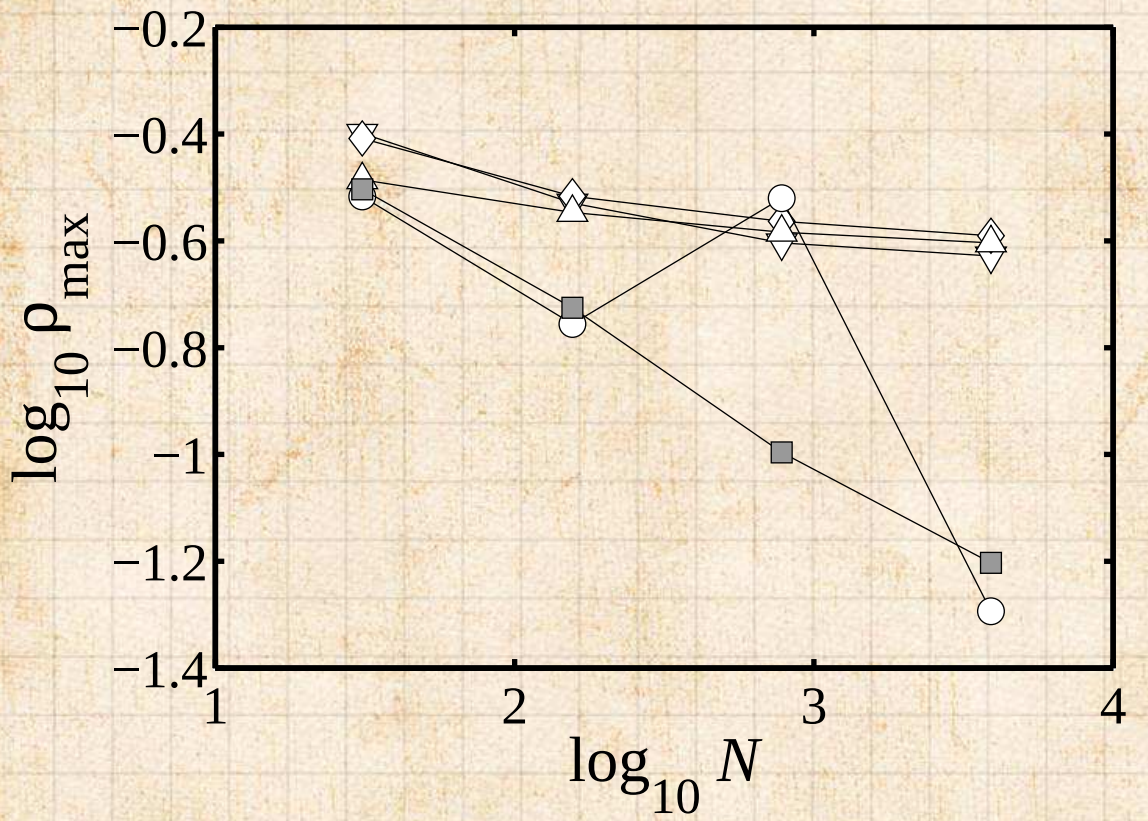


Results—Maximum firm size

- 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: $\xi = \infty$



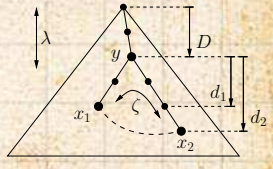
◇=TB

▽=R

△=RID

○=CP

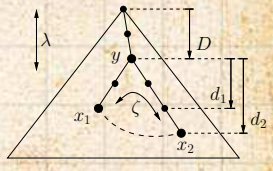
□=MS



Connectivity Robustness

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.

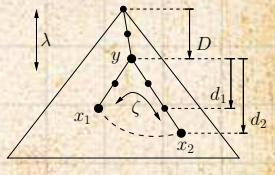


Connectivity Robustness

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

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.

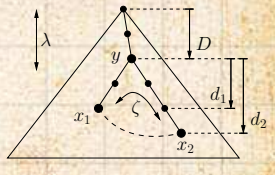


Connectivity Robustness

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

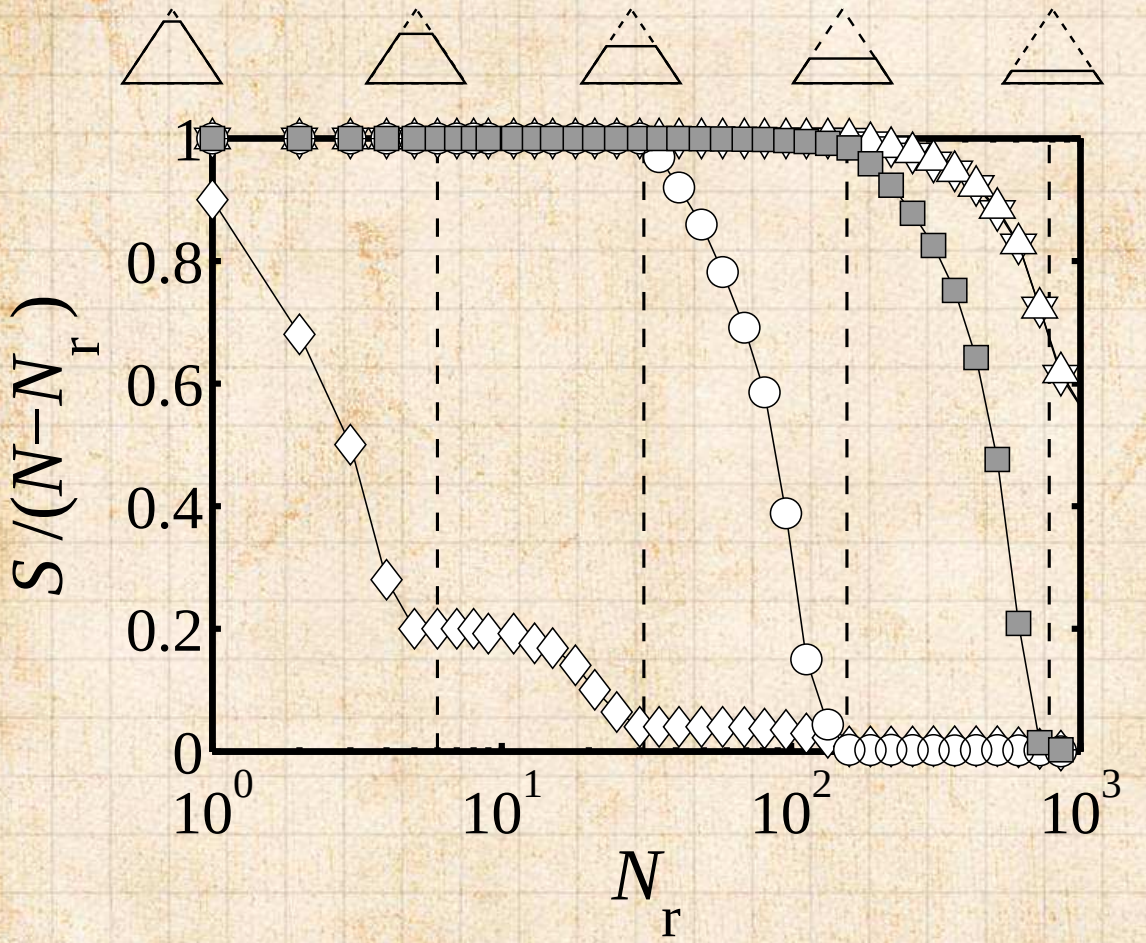
Inducing catastrophic failure:

- 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.



Results—Connectivity Robustness

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References



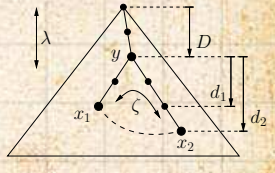
◇=TB

▽=R

△=RID

○=CP

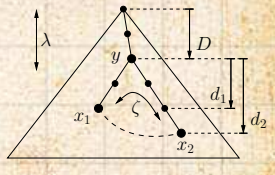
□=MS



Summary of results

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

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



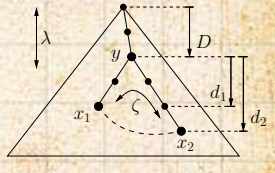
Conclusary moments

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

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.



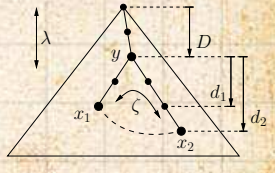
Conclusary moments

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

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.



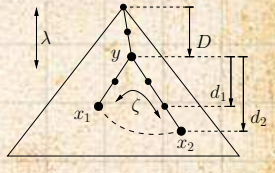
Conclusary moments

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

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.



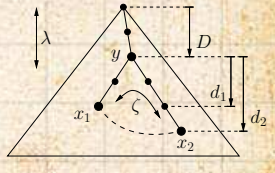
Conclusary moments

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

Multi-scale networks:

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

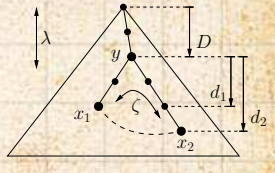
Above suggests existence of multi-scale structure is plausible.



Conclusary moments

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

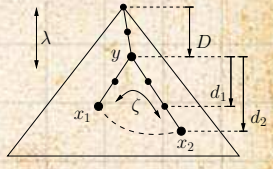
- Foregoing is an attempt to model what organizations might look like beyond simple hierarchies (2003).
- Possible work: develop 'bottom up' model of organizational networks based on social search, identity (emergent searchability).
- Balance of generalists versus specialists—how many middle managers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



Conclusary moments

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

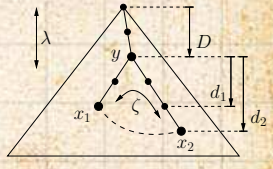
- Foregoing is an attempt to model what organizations might look like beyond simple hierarchies (2003).
- Possible work: develop ‘bottom up’ model of organizational networks based on social search, identity (emergent searchability).
- Balance of generalists versus specialists—how many middle managers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



Conclusary moments

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

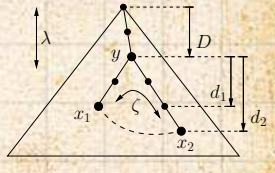
- Foregoing is an attempt to model what organizations might look like beyond simple hierarchies (2003).
- Possible work: develop ‘bottom up’ model of organizational networks based on social search, identity (emergent searchability).
- Balance of generalists versus specialists—how many middle managers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



Conclusary moments

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

- 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...



References I

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

[1] R. H. Coase.

The nature of the firm.

Economica, New Series, 4(4):386–405, 1937. pdf

[2] P. S. Dodds, D. J. Watts, and C. F. Sabel.

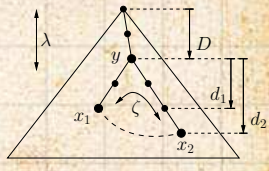
Information exchange and the robustness of organizational networks.

Proc. Natl. Acad. Sci., 100(21):12516–12521, 2003. pdf

[3] R. Guimerà, A. Dıaz-Guilera, F. Vega-Redondo, A. Cabrales, and A. A.

Optimal network topologies for local search with congestion.

Phys. Rev. Lett., 89:248701, 2002. pdf



References II

[4] T. Nishiguchi and A. Beaudet.

Fractal design: Self-organizing links in supply chain.

In G. Von Krogh, I. Nonaka, and T. Nishiguchi, editors, Knowledge Creation: A New Source of Value, pages 199–230. MacMillan, London, 2000.

[5] R. Radner.

The organization of decentralized information processing.

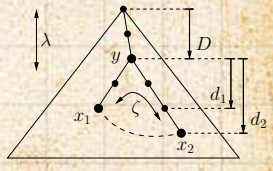
Econometrica, 61(5):1109–1146, 1993. pdf

[6] D. Stark.

Heterarchy.

In J. Clippinger, editor, The Biology of Business: Decoding the Natural Laws of the Enterprise., chapter 5, pages 153–. Jossey-Bass, San Francisco, 1999. pdf

Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References



References III

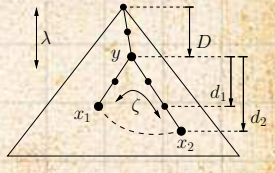
Overview
Toyota
Ambiguous problems
Models of organizations:
Modelification
Goals
Model
Testing
Results
Conclusion
References

[7] T. Van Zandt.

Organizations with an endogenous number of information processing agents.

In Organizations with Incomplete Information, chapter 7. Cambridge University Press, New York, 1998.

[8] D. J. Watts, P. S. Dodds, and M. E. J. Newman.

Identity and search in social networks.

Science, 296:1302–1305, 2002. pdf