Analysis of a network based on joint patent applications: from a view point of geographic proximity

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Networks and innovation

An important function of industrial clusters is to provide organizational networks in order to realize innovation.

Cooperative R&D network is one of the networks. However the structure and the growing process of the network has not been studied in Japan.

We focus on the analysis of this cooperative R&D network.

Rapid progress of network science

Graph theory

- Konigsberg bridge

Social network analysis

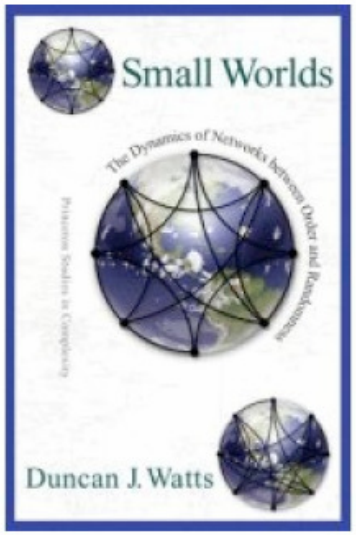
- Strength of weak tie

Statistical physics

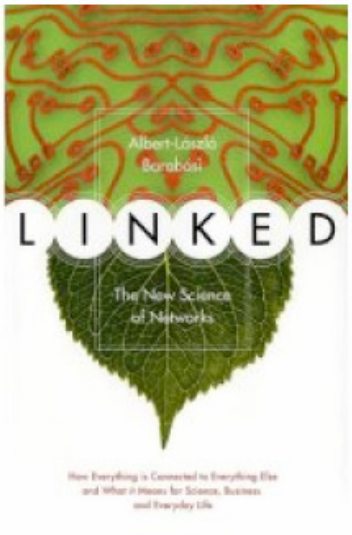
- Phase transition, critical phenomenon, fractal

Network science

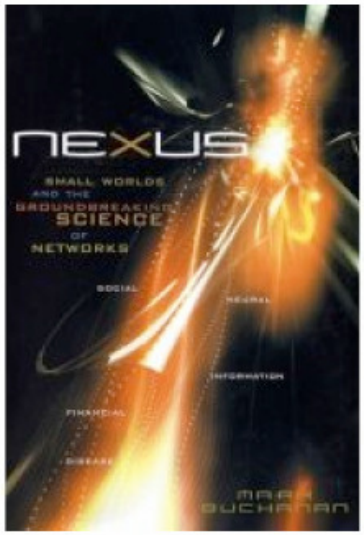
Recently published books



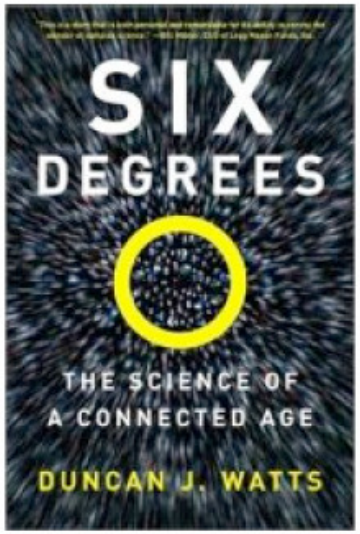
Watts 1999



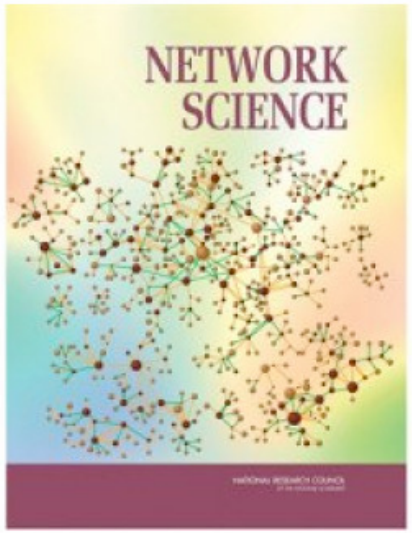
Barabási 2002



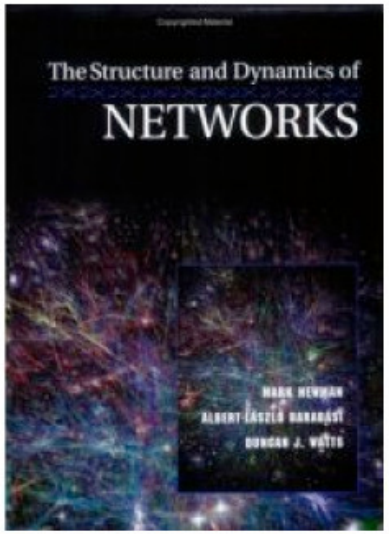
Buchanan 2002



Watts 2003



National Research Council (U.S.) 2005



Newman, et al. 2006

Objective

- Analysis of a network based on joint patent applications
- Estimation of a growth model for the network.

Cooperative R&D and patents

Companies do not disclose cooperative R&D activities.

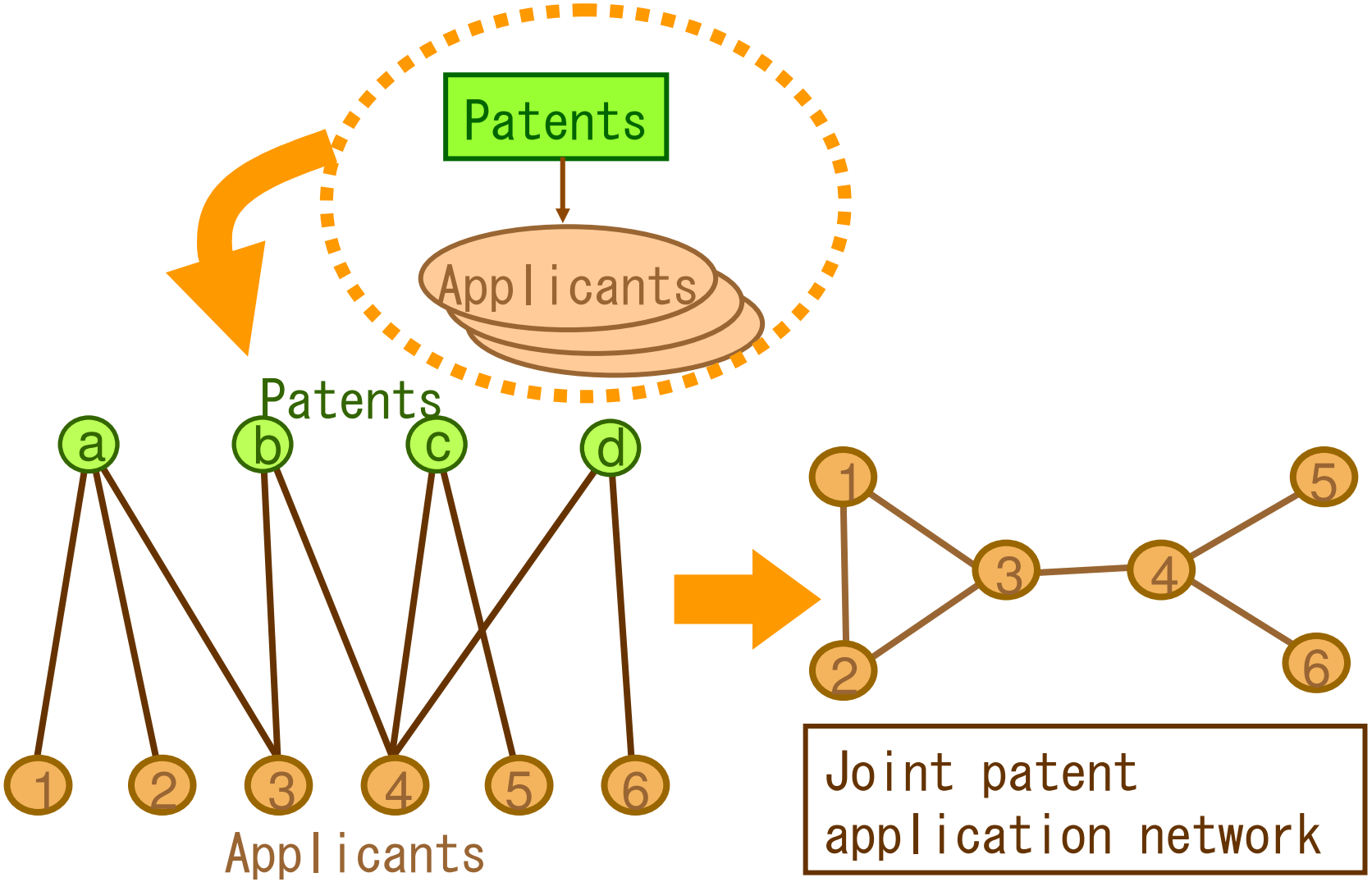
Patents show the activities as joint applications.

Note:
Joint patent applications are only part of
results of cooperative R&D.
However, we can consider the structure of cooperative R&D
is similar to one of joint patent applications.

Japanese patents database

Period	1994 - 2003
Num. of patents	4,998,464
Utilized data	Applicant name, Applicant address, Inventor address

How to create a patent network

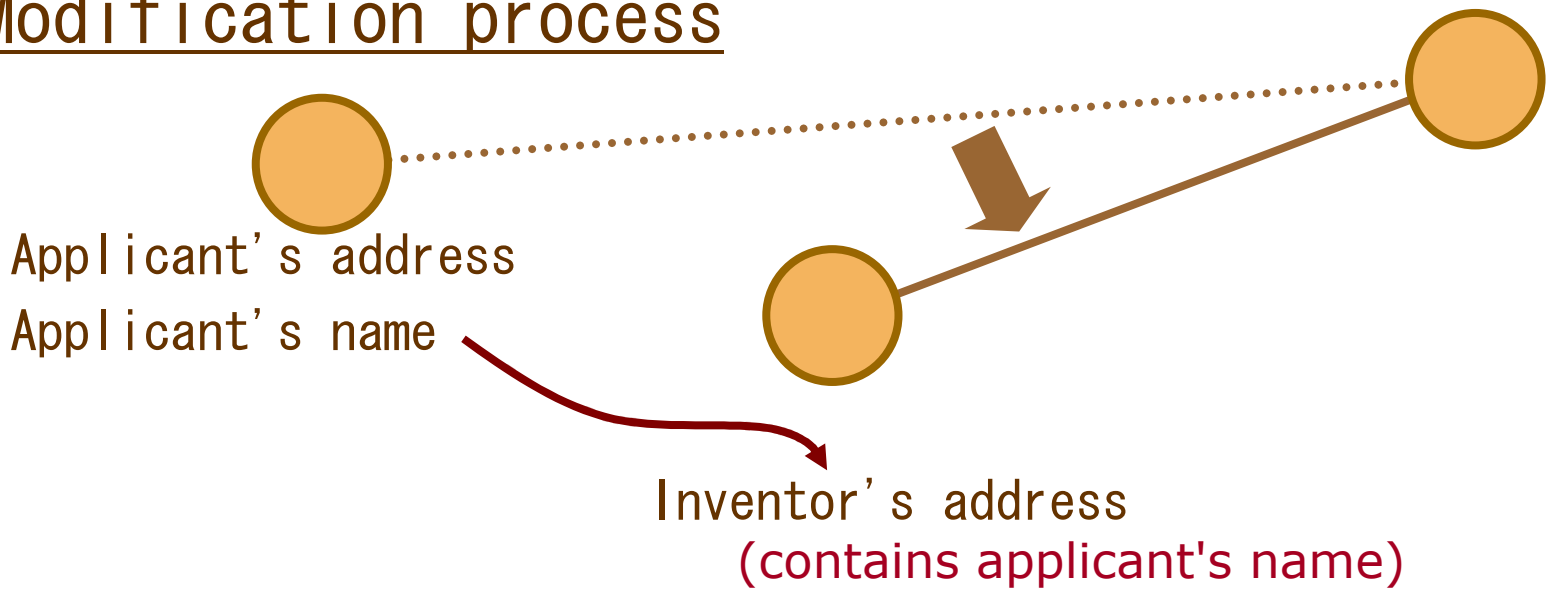


Modifying nodes' addresses

Applicants (Organizations) can have multiple offices.

We need exact places where the inventions occured.
However, an applicant only has the address of the headquarter.

Modification process



How much is it modified?

The modification is necessary.

Num. of increased nodes	29,430 (118.8%↑)
Num. of increased links	49,117 (46.7%↑)

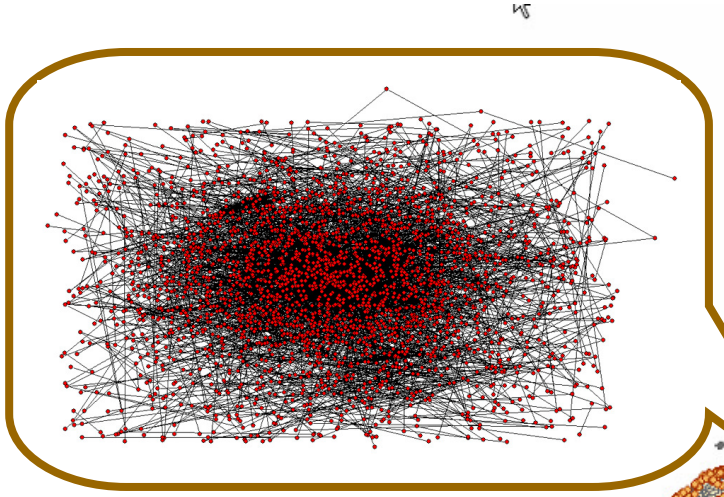
Nodes	Applicants
Num.of nodes	24,767
Num.of links	105,088

Before

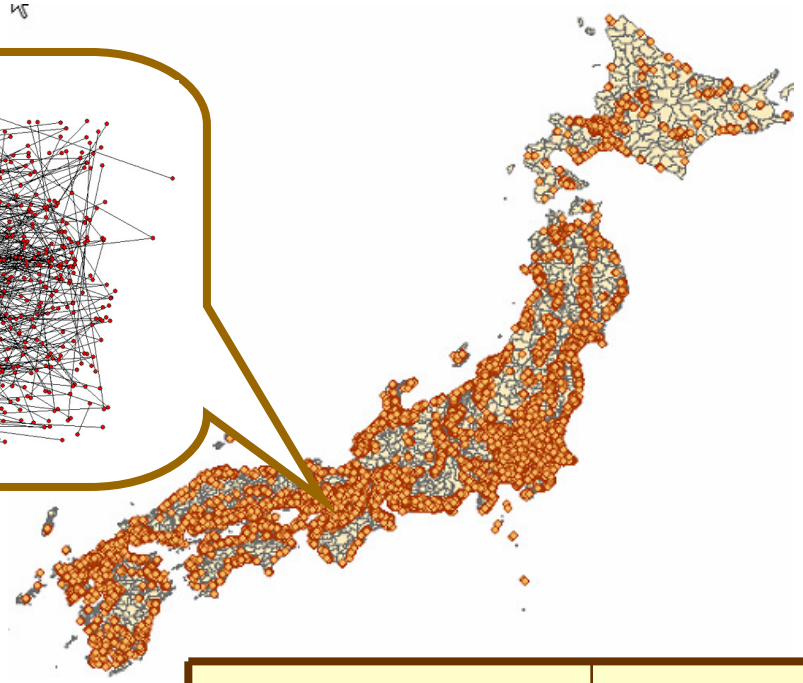
Nodes	Applicants (+Inventors)
Num.of nodes	54,197
Num.of links	154,205

After

Appearance of the network



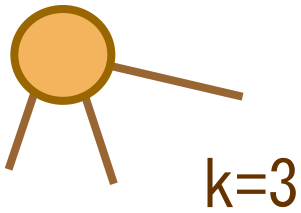
Osaka (example)

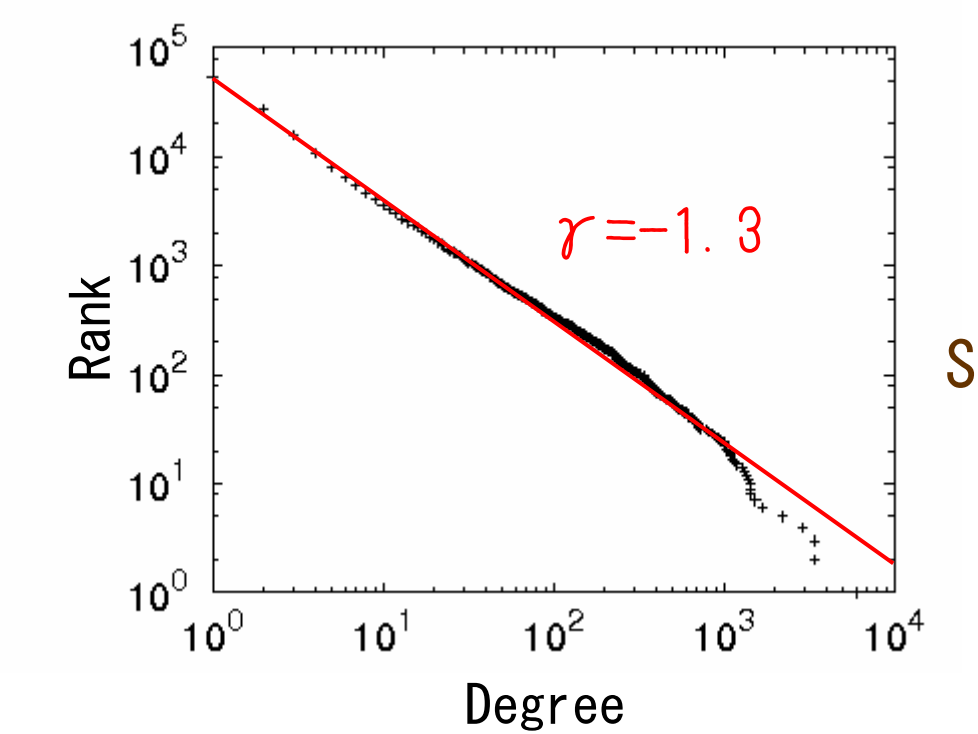


Num. of nodes	54,197
Num. of links	154,205

Degree distribution

Degree: Number of links a node has

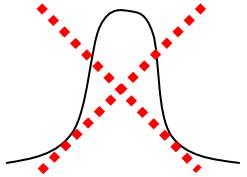




$P \propto k^{-1.3}$

$p \propto k^{-2.3}$

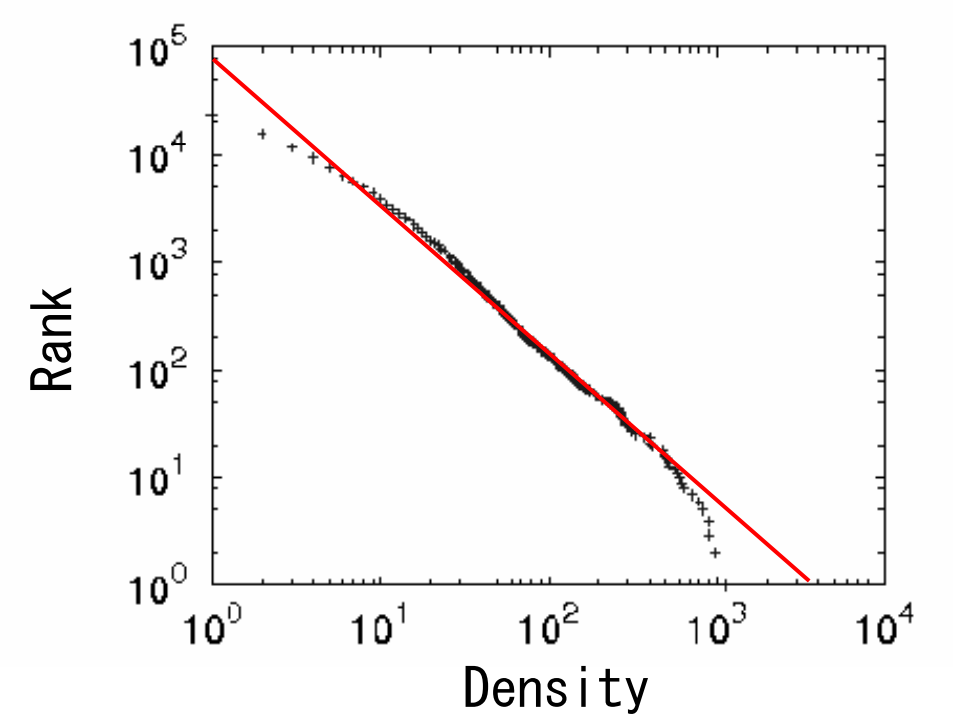
Scale-free network



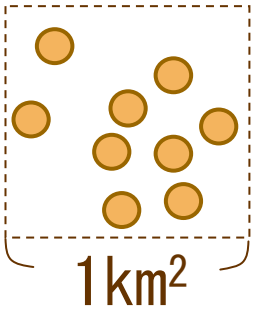
no typical degree

Density distribusion

Node density: Number of nodes in 1 square km

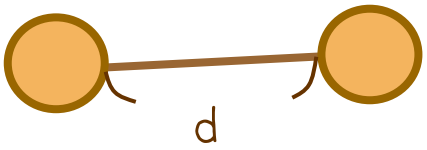


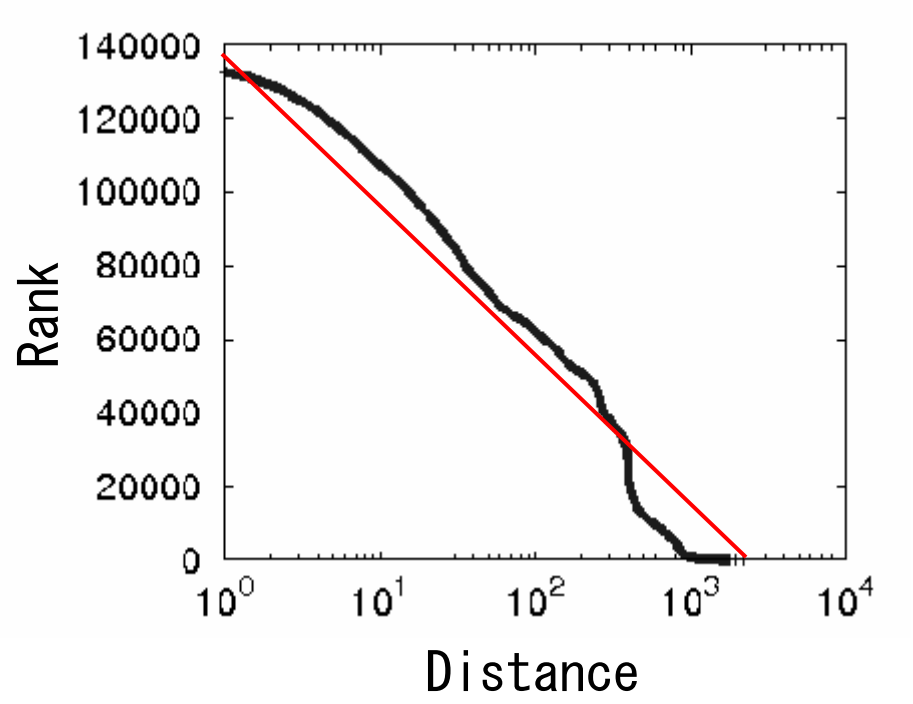
$P \propto d^{-1.4}$



Link distance distribution

Link distance: Geodesic distance of a link between two nodes





$P \propto -\log(d)$

$\updownarrow$

$p \propto 1/d$

Empirical hypothesis is confirmed.

How does the network grow?

We know the structures of the network.

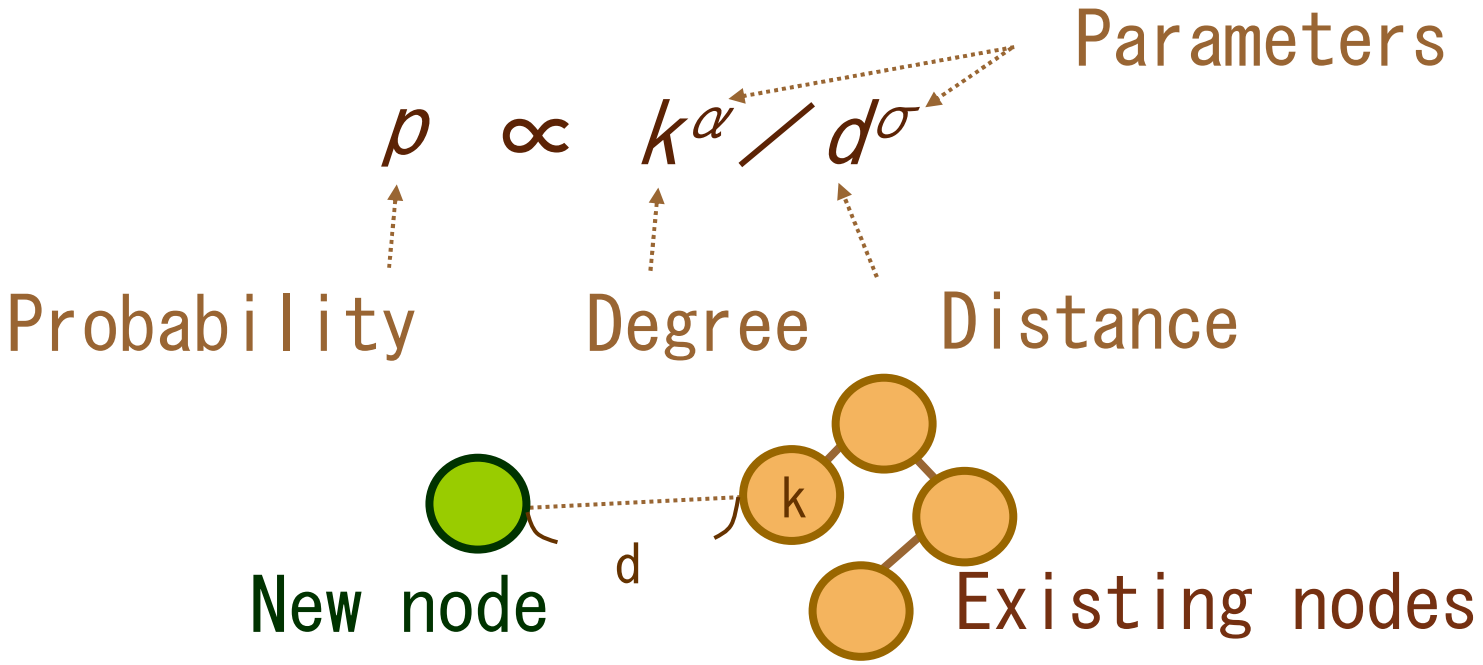
What kind of rules of growth

does the structures have?

- If we know the rules,
  we can understand how organizations
  try to connect each other.

A growth model of networks

The model is defined by the probability for choosing one of existing nodes to create a link with a new added node.



Verification

$$p \propto k^{\alpha} / d^{\sigma}$$

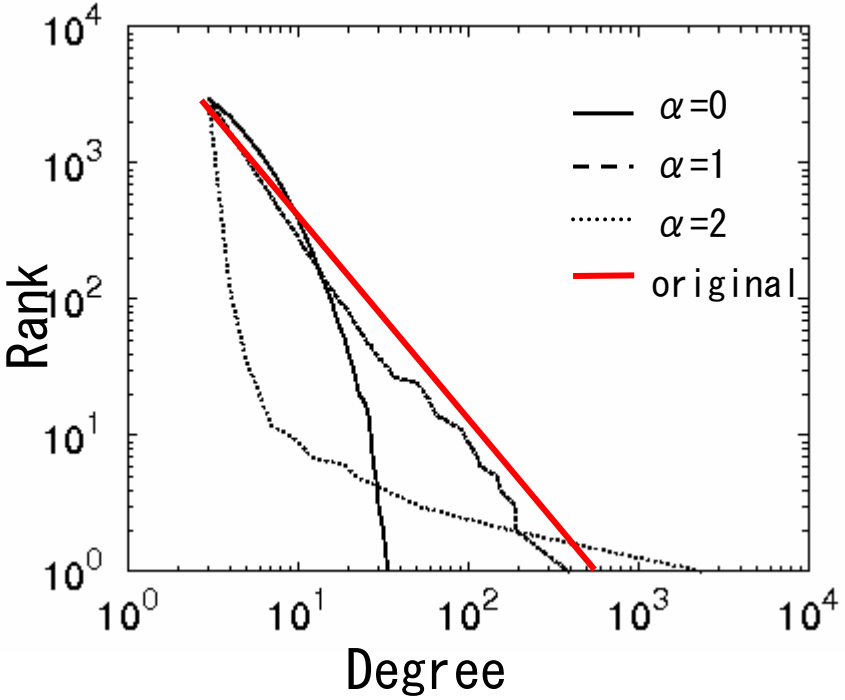
α=0,1,2 and σ=1

α=1 and σ=0,1,2 → 6 combinations were tried.

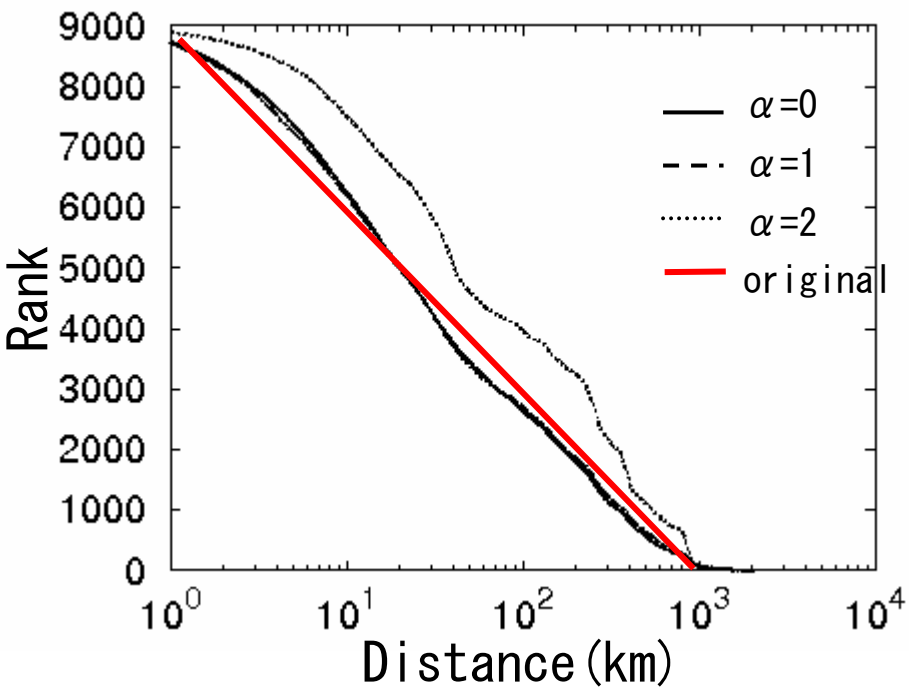
σ=1, α=0, 1, 2

$p \propto k^{\alpha}/d^{\sigma}$

Degree distribution



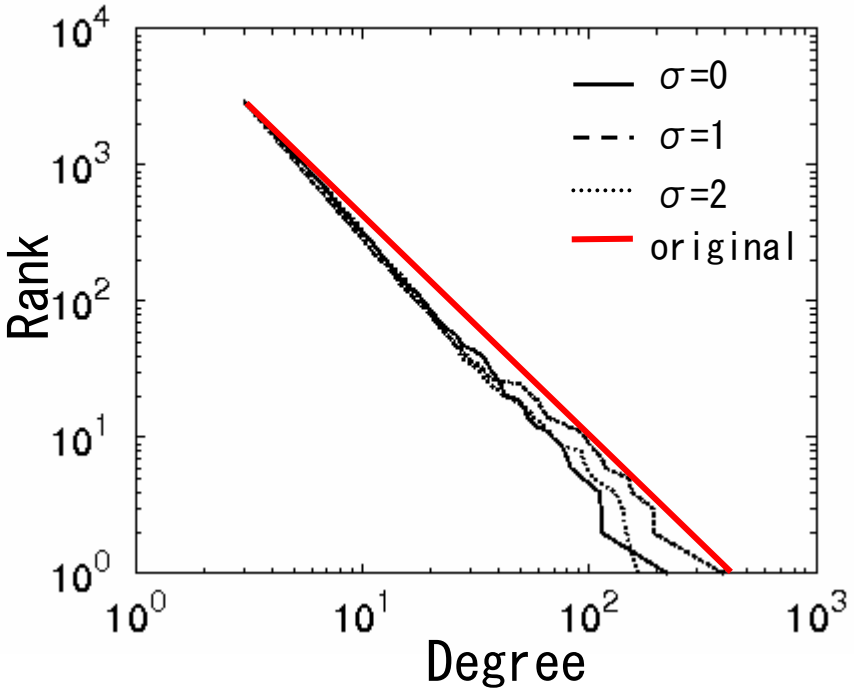
Link distance distribution



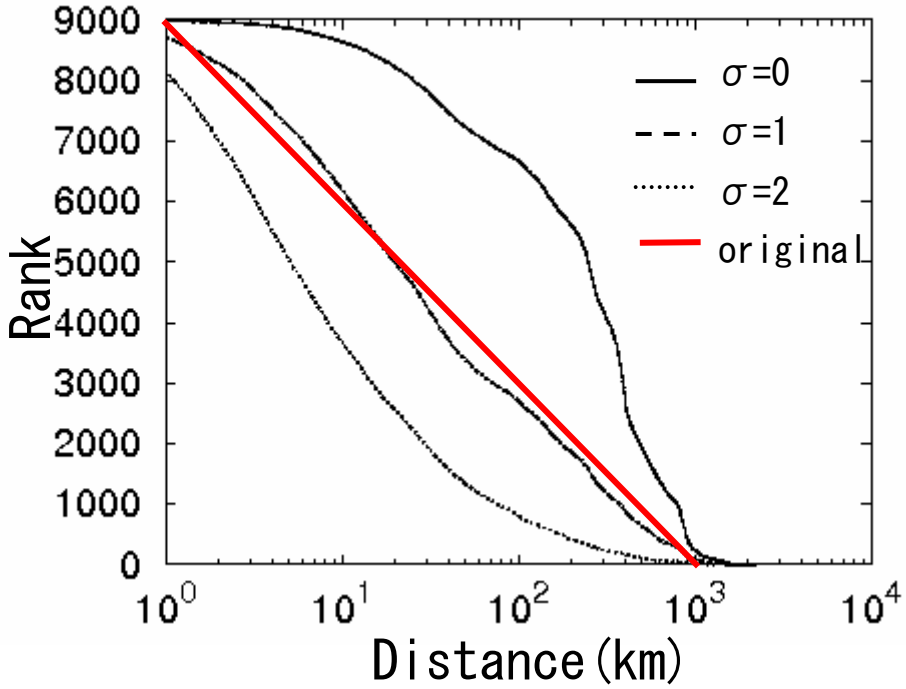
α=1, σ=0, 1, 2

$p \propto k^{\alpha}/d^{\sigma}$

Degree distribution



Link distance distribution



Discussion

Significance of the results:

the balance in the probability　(p ∝ k/d)

→degree and link distance are important equivalently

A small company does not have many links generally.

→chance for getting links is small

However, they can use geographical advantage which all companies can equally utilize.

This analysis supports the concept of industrial clusters.

Conclusion

We analyzed the joint patent application network and verified a growth model.

Original network

Degree and node density distribusion follow power laws.
Link distance distribusion shows an inverse proportion.

Growth model

$p \propto k/d$ reproduce several structures of the original network.