Track2a-3:

Emergence of Global Network Property based on Multi-agent Voting Model

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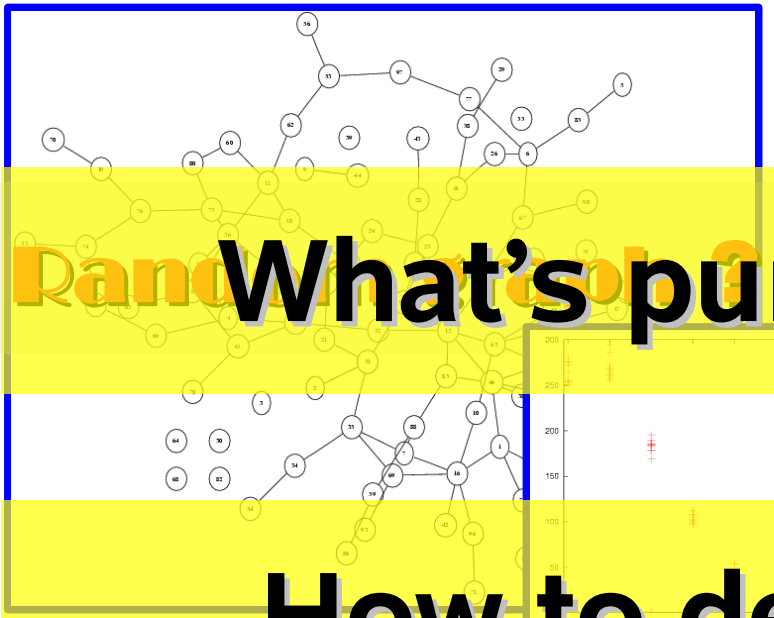
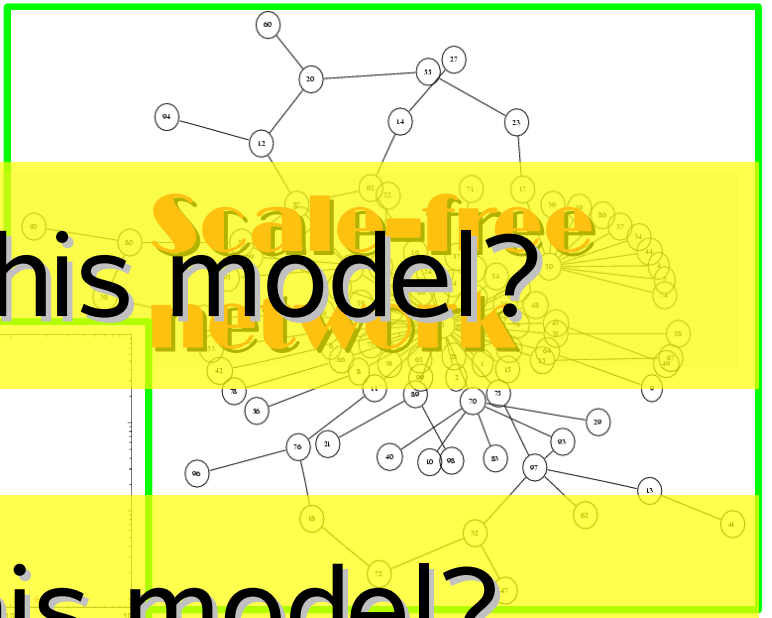
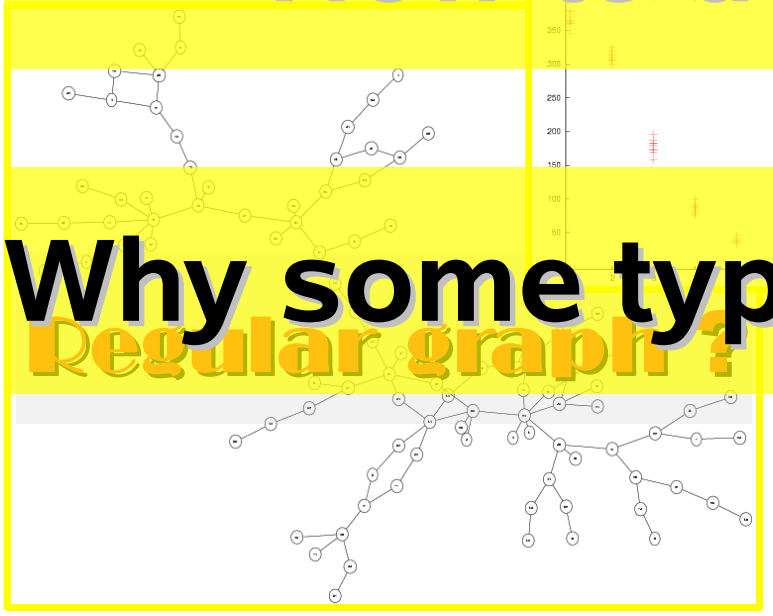
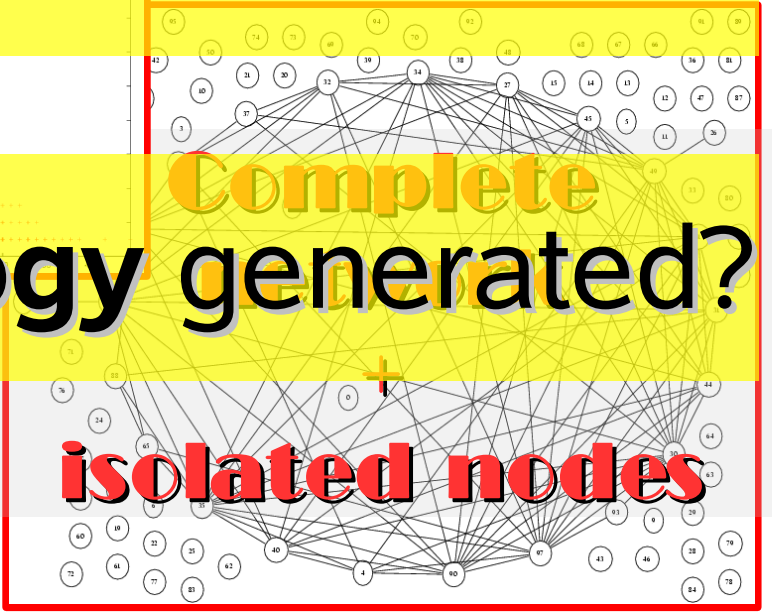
Our model generates 4 types of network









What's purpose of this model?

How to design is this model?

Why some types topology generated?

Outlines

- Our research Background
- Simulation model of Network Growing based on Multi-agent model
  - Problem setting & simulation steps.
  - Network centrality
- Results and overall properties
- Conclusions and Future Works

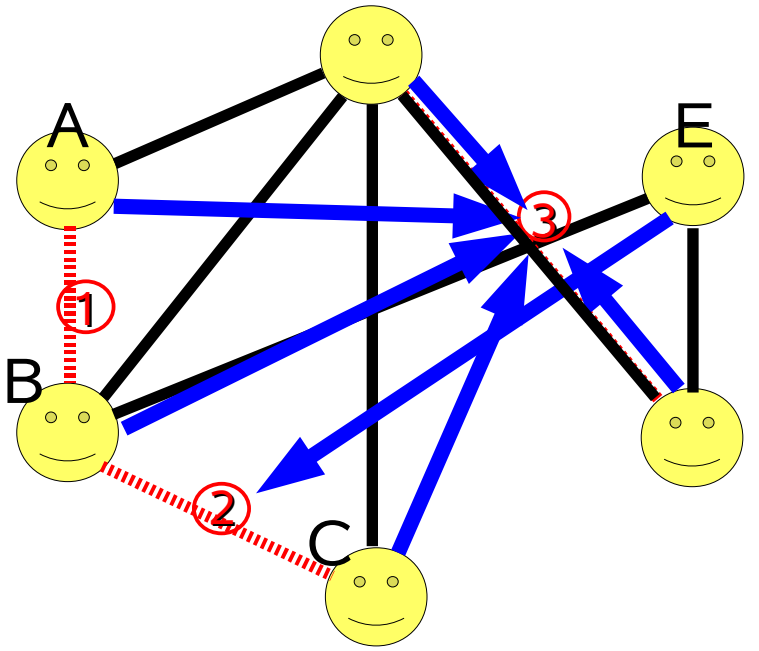
Background

- We aim to **examine the application to social network system** such as information recommendation, but, **a few studies** have been conducted into the nature of local behavior and global network properties.
  - Agent Simulations with network topology
    - Those studies have revealed that the **overall performance** is markedly influenced by the network structure among agents.
- We have to model considering with **node's goal** on network
  - Network generating models(ex. Scale-Free,Small-World)
    - Those defined a node as objects who has little autonomy.

· **A growing network model from the agent views.**
  · How local interaction and agreement among agents consists difference network properties
  · The preliminary analysis of an actual social network

Simulation Model

- Problem Setting of network generation:
  - Each agent is considered as a node
  - A new edge is generated through agreements among agents, as recorded through a voting.
  - The newly invented edge increases the respective utilities of some agents.
  - This process is iterated and the network becomes more connected
- When agents vote, they use a centrality for a utility functions, and seek to increase own centrality.
  - Degree, closeness, betweenness, pagerank



Network Centrality

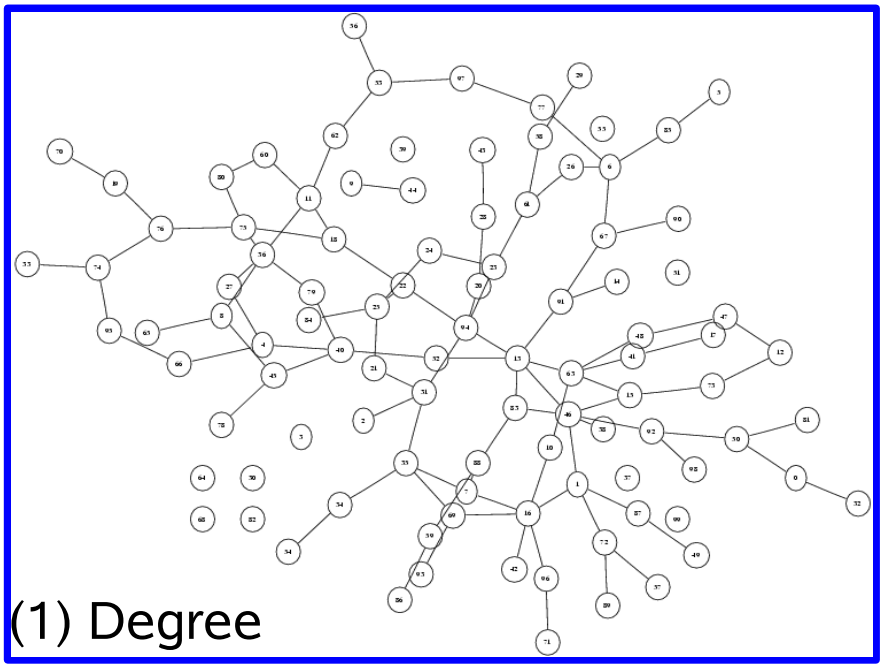
- Centrality represents the **importance of nodes**. The most popular centralities are as following;

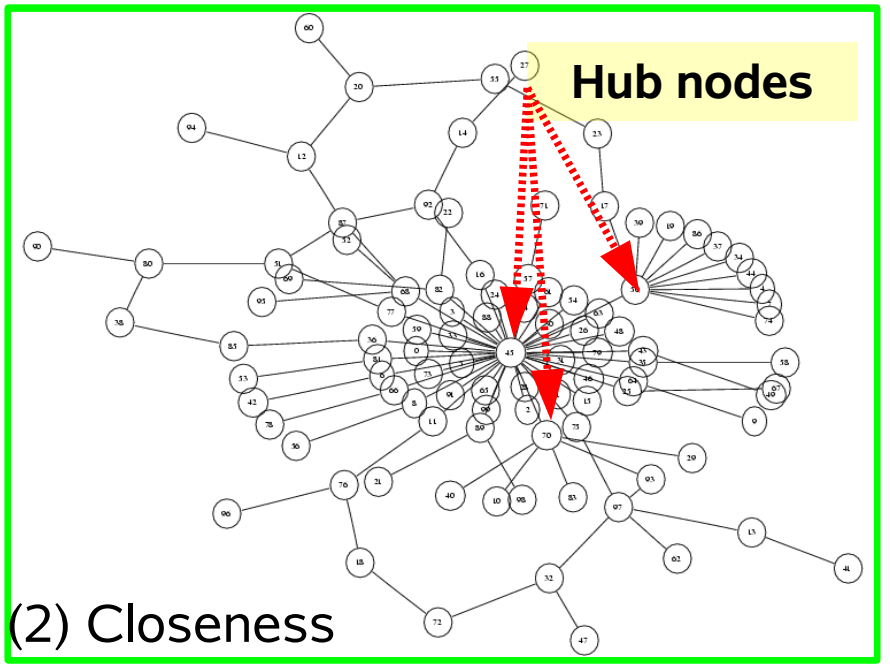
  1. Degree:
     - Degree means ***how many acquaintances*** a node has. This value is presented the number of edges to other nodes.
  2. Closeness:
     - This captures ***how close a node is to all*** the other one. This value is calculated by the minimum distance of a node to all other nodes.
  3. Betweenness:
     - Betweenness indicates that a node is in ***a favored position of information flow***. It measures the number of all the shortest paths that go through the nodes.
  4. PageRank:
     - PageRank was proposed as ***a measure of the importance of a Web*** Page. We use PageRank because of its familiarity to computer science researcher.

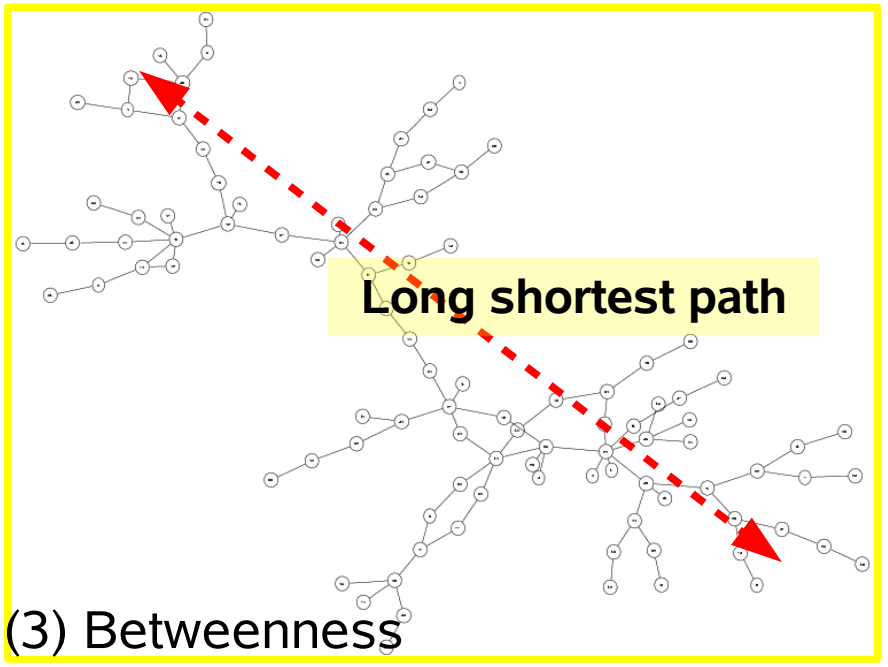
- These Centrality are used as a proxy for utility, which is to be maximized.

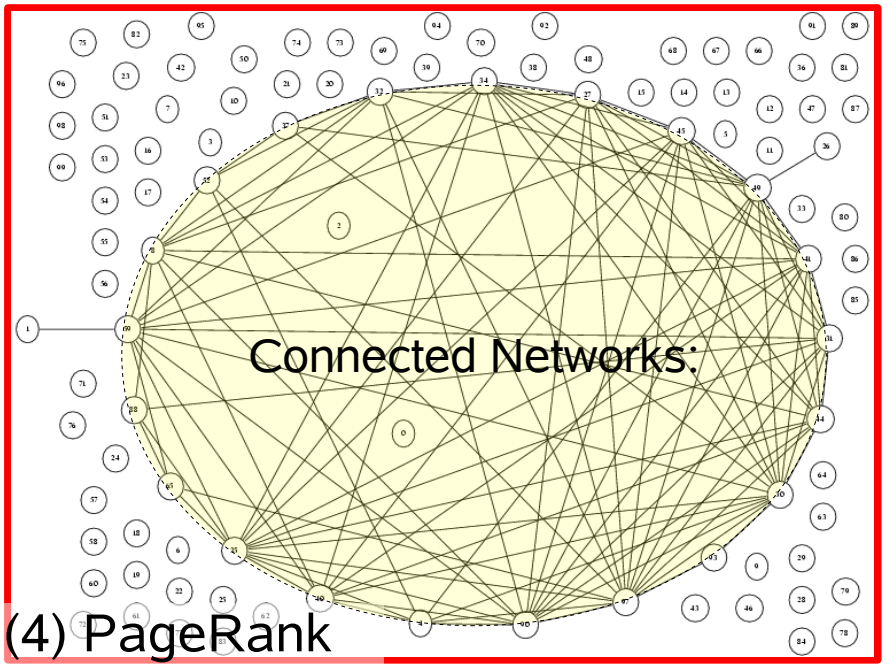
RESULTS
and
OVERALL PROPERTYE

Figure of Networks





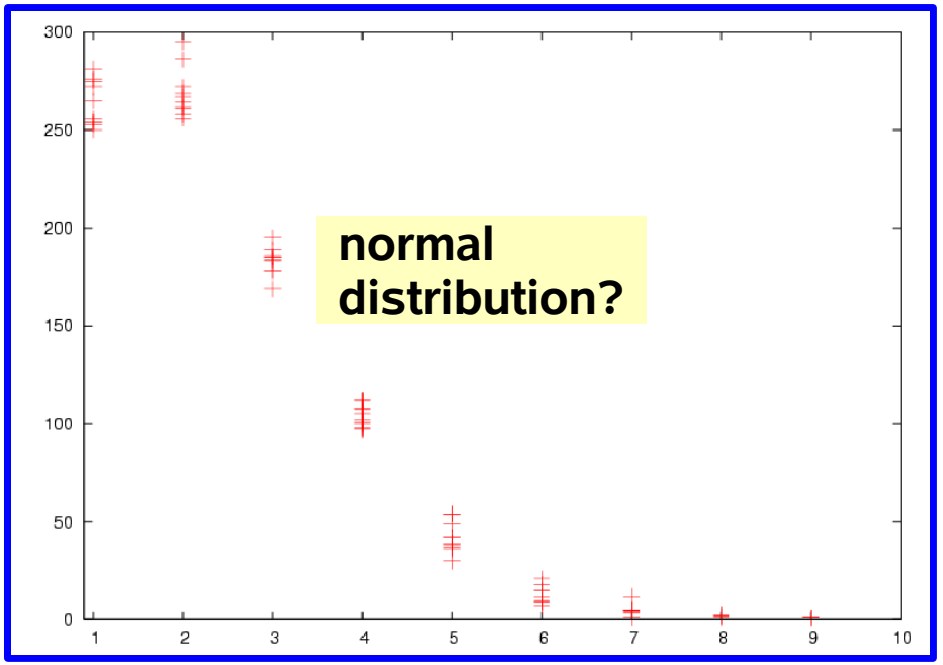


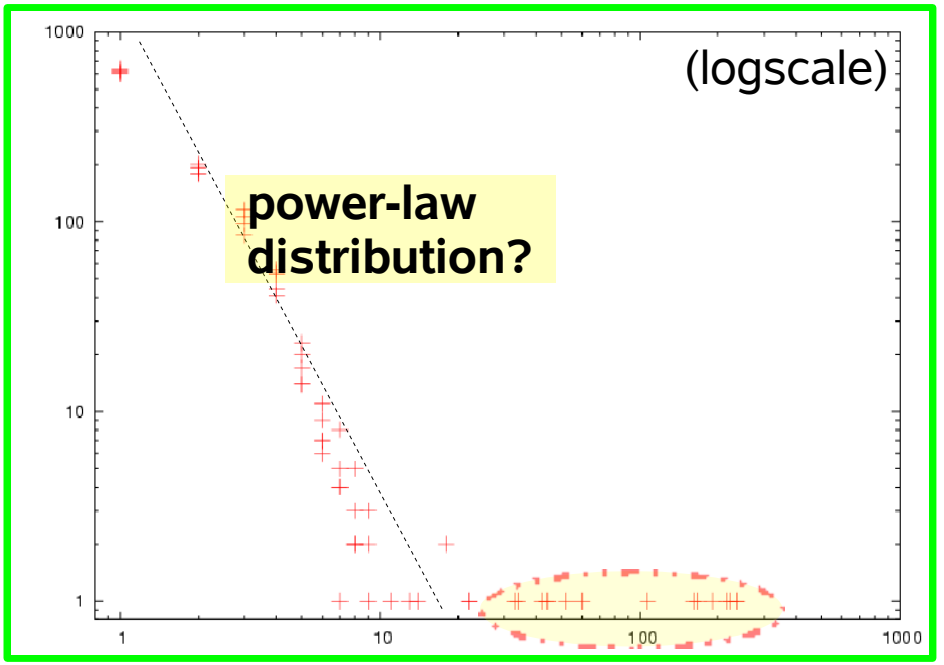


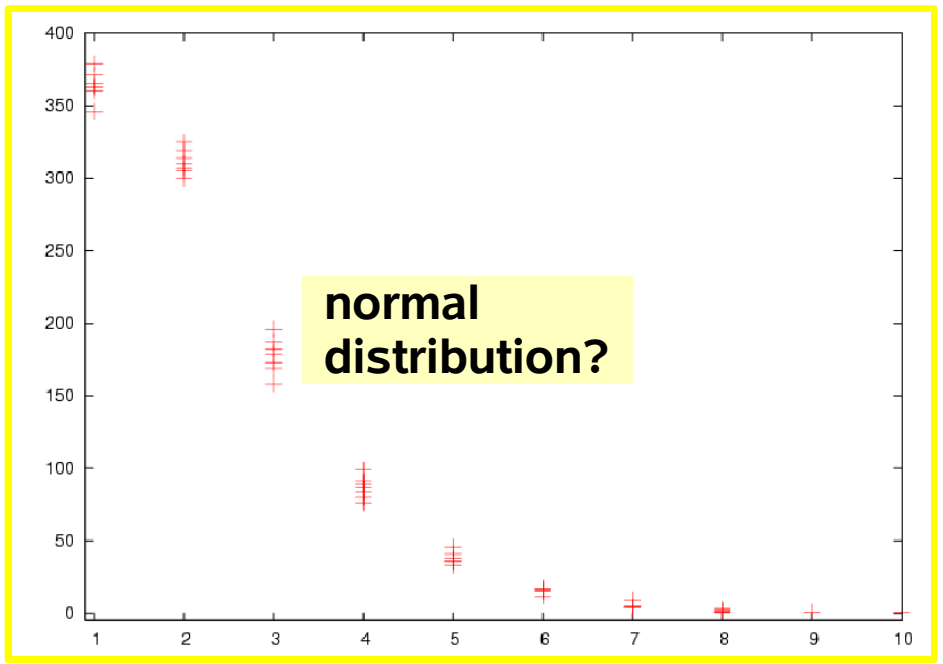
Note: The position and distance of nodes imply nothing, illustrated by graphviz.

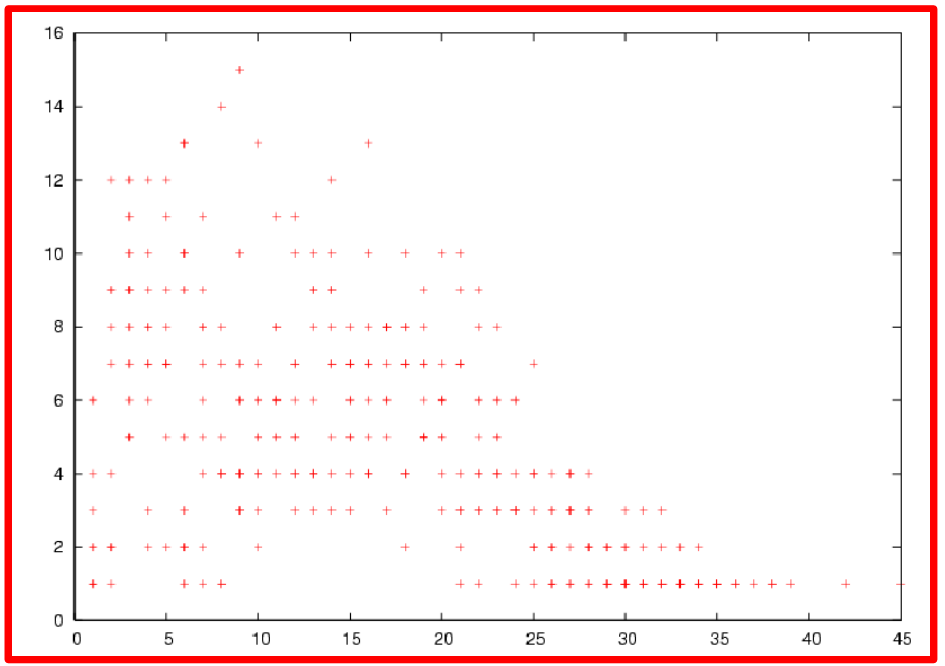
N=100, <k>=2.1. c=200

Degree Distributions









N=1000, <k>=2.1, c=200

What caused these network topologies to emerge?

- Degree
  - Each agent interests only in edges which is one end, so that newly edge is selected at random.
- Closeness
  - The edge **between a hub and an isolated node** gets the **most votes**, which makes a hub more connected and stronger. This insights that closeness is important factor in scale-free network, such as airline network.
- Betweenness
  - To be **big betweenness** need a **Large shortest path**, so that network tends to have large *L* and *D*. This means that betweenness has some relations with a network has large *L and D*, such as highway, train route.
- PageRank
  - PageRank **makes a dense connected component** with numerous edge; the number of the **connected component** increases very **slowly.** Such a situation is sometimes observed in real-world social networks such as OTAKU groups.

Future Works
and
Conclusion

Discussion

- Some elements were neglected in our model
  - Edges are **monotonously increasing.**
    - It is necessary to consider the **dissolving the relations**.
  - Centrality measures **require whole network topology.**
    - In this research, we use network-centric centrality, however we need to use **ego-centric centrality** to construct network growing model from the agent view.
  - **Homogeneous** agents
    - Some actual networks consist of **heterogeneous agents**.
  - Negotiation process of agreements is vote **among all gents**
    - c.f. Network Gaming is agreement between two nodes.

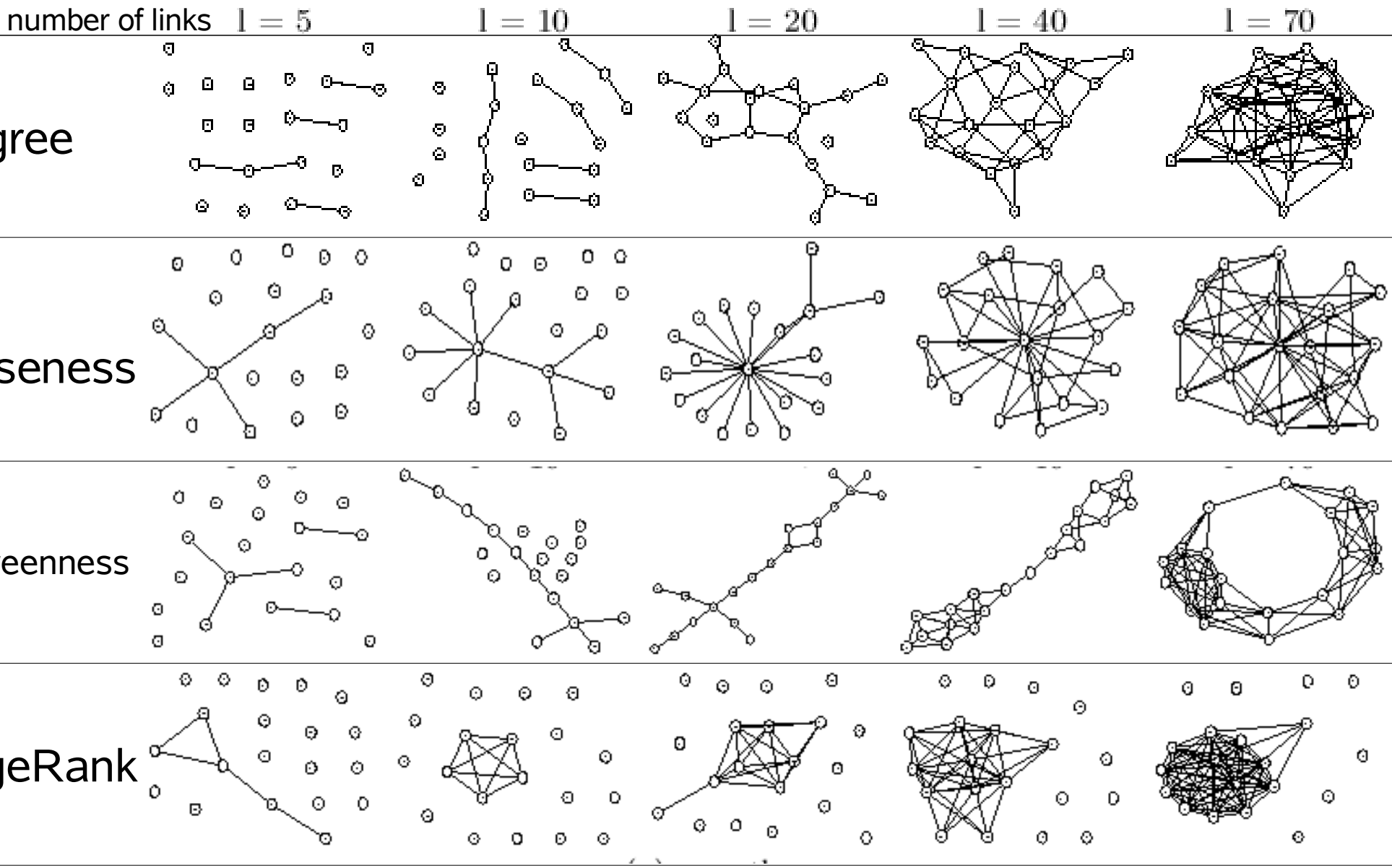
Conclusion

- We proposed an model of growing network.
  - A network was generated by voting among agents
  - Each agent behaves to increase own utility on network.
- Different centrality measures engender different networks:
  - Degree: a random network
  - Closeness : a scale-free network
  - Betweenness: a regular graph
  - PageRank: a complete graph
- This research provides insights toward global properties and local decision from the multi-agent perspectives.

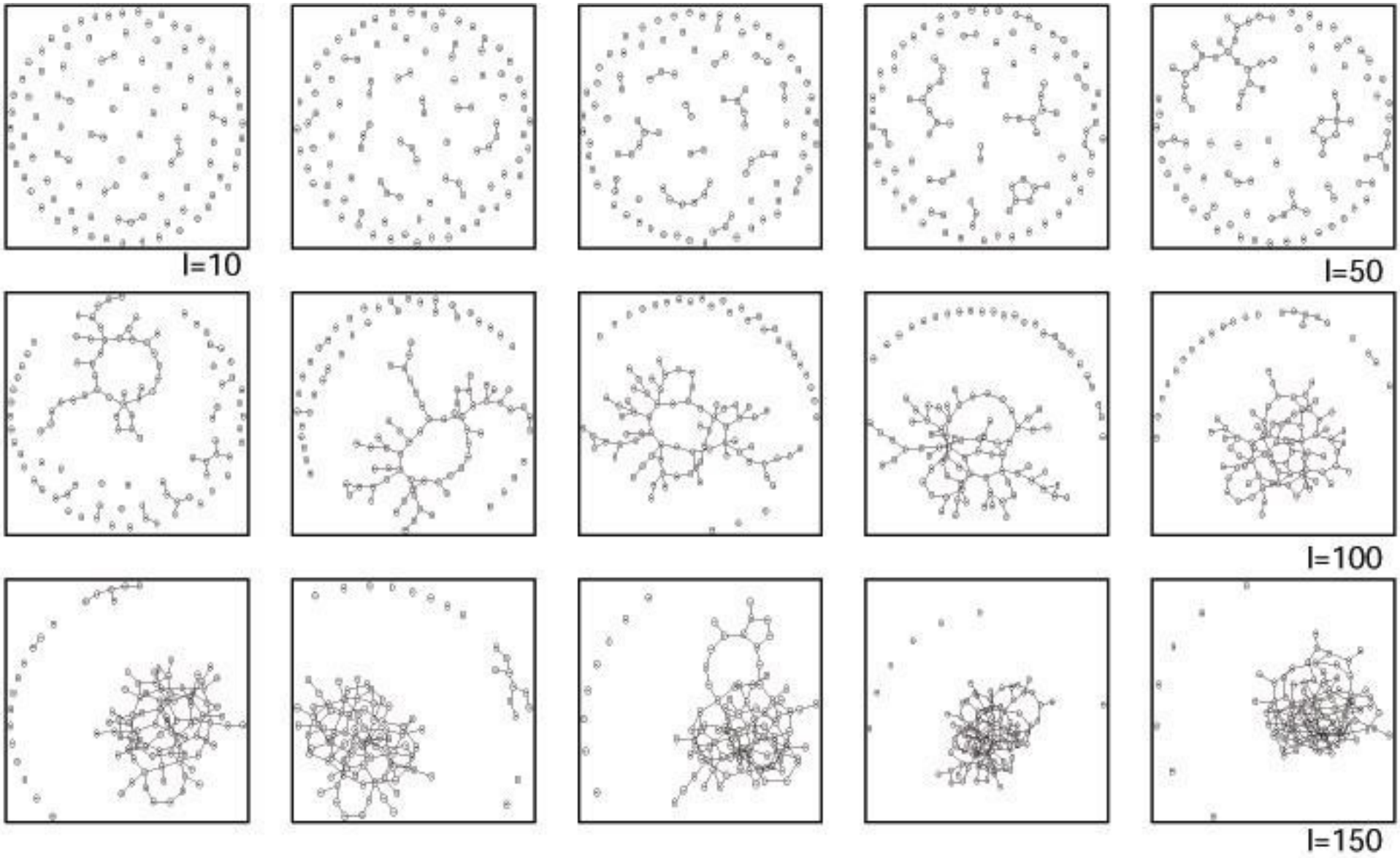
Future Works

- We can use our model in various kinds of multi-agent simulation, especially of social systems
  - Recommendation system in academic conference.
  - Region network design; transport, material flow.
  - The evaluation of team-formation, such as football, basketball.
- The stainability of networked society.
  - culture, knowledge accumulated, economy, etc.

Process of network growing(N=20)

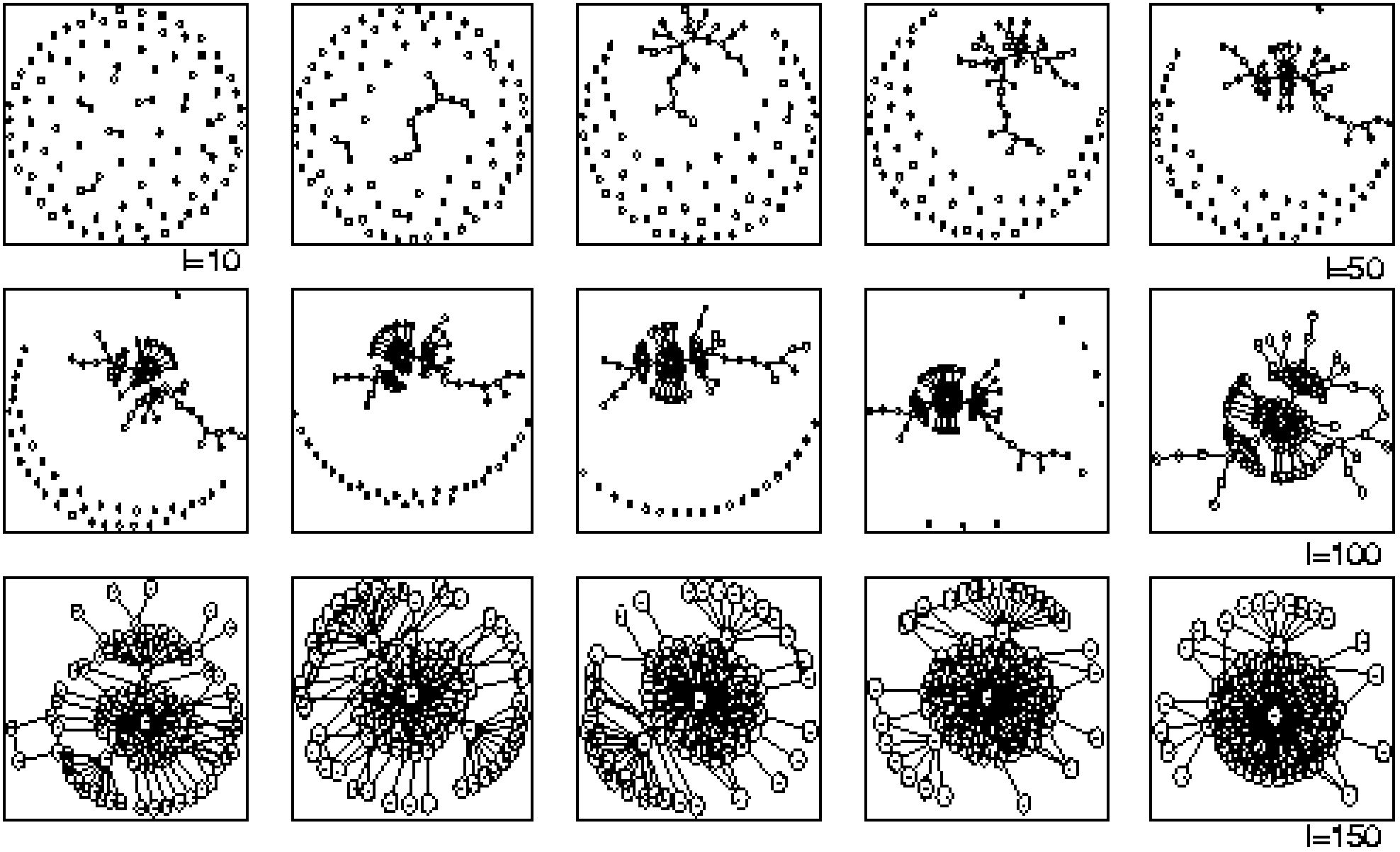


The growth process of Degree



N=100, c=200

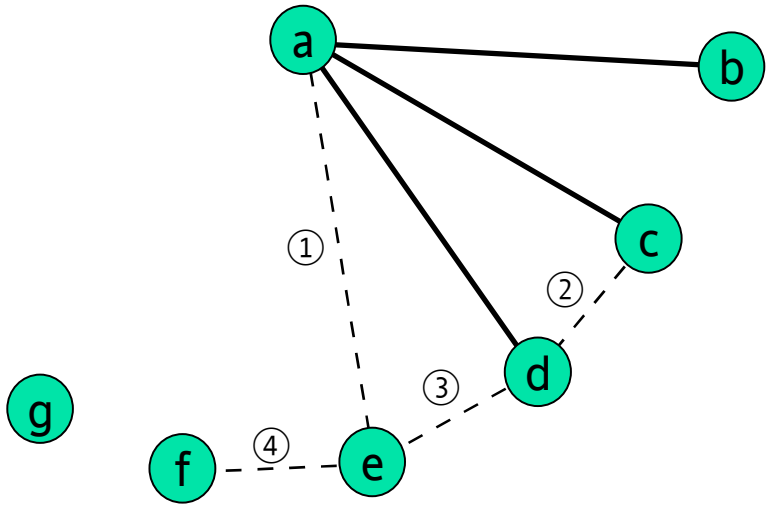
The growth process of Closeness



N=100, c=200

The mechanism with closeness centrality

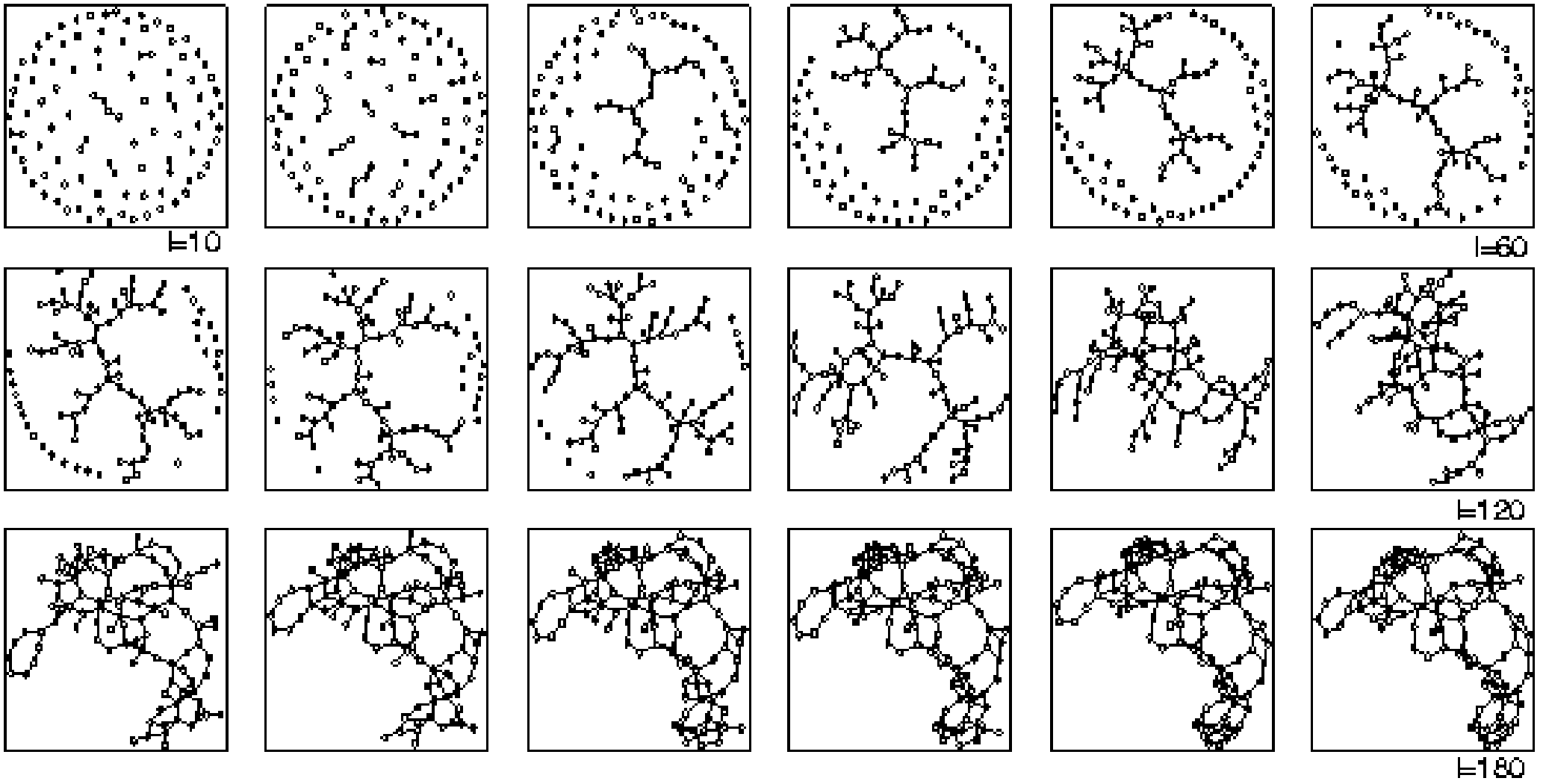
- In case of four characteristic candidate edges
  - 1) between a hub node and a connected node
  - 2) between two connected nodes,
  - 3) between a connected node and an isolated node,
  - 4) between two isolated nodes
- All agents want to be selected a link belongs a node that has a high closeness centrality.



Expected Value of closeness centrality

	a	b	c	d	e	f	g	score
1)	3	3	3	2	3	1	1.5	15
2)	0.5	0.5	0.5	0.5	0	1	1.5	3
3)	2	2	2	3	2	1	1.5	12
4)	0.5	0.5	0.5	0.5	1	3	1.5	3

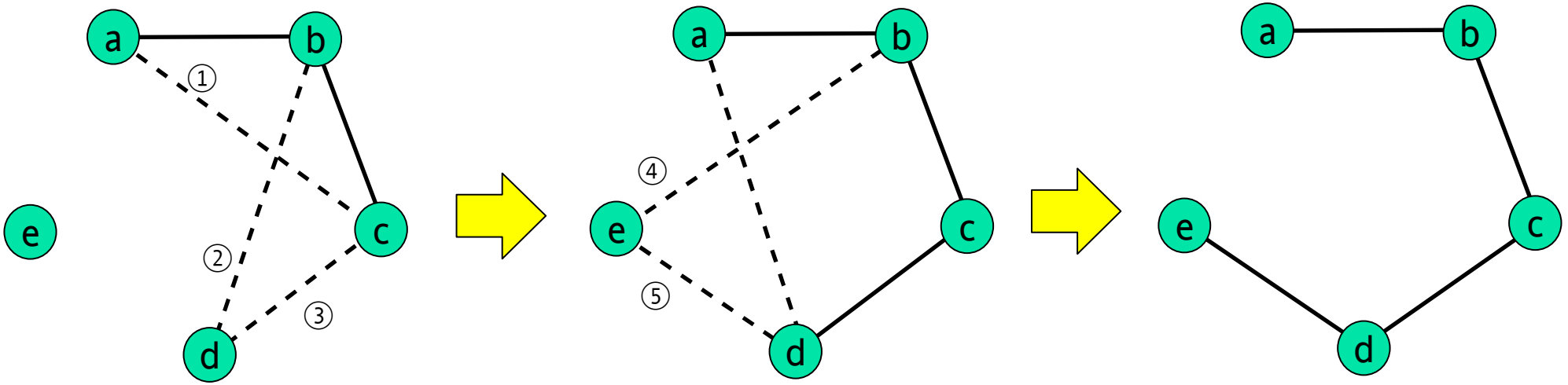
The growth process of Betweenness



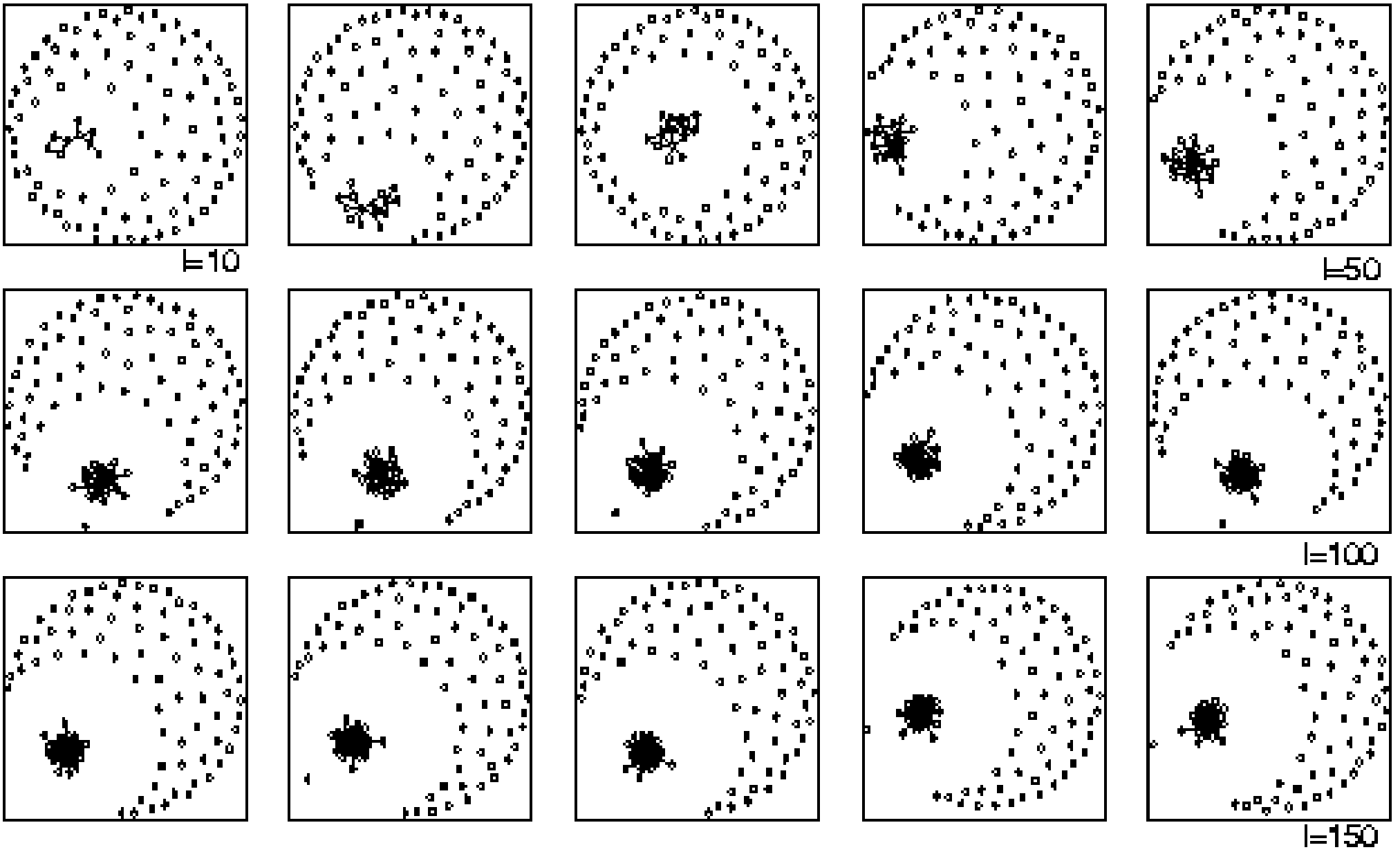
N=100, c=200

The mechanism with betweenness centrality

- The mainly type of candidate edges:
  - between two connected nodes,
  - between a connected node(has some betweeness) and an isolated node
  - betweenn a connected node(has no betweenness) and an isolated node
- A node's betweenness raise when geodesic path pass through its node increases.



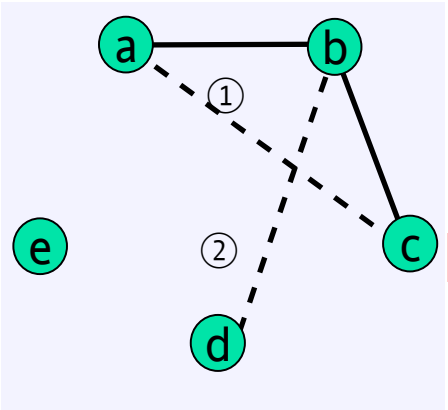
The growth process of PageRank



N=100, c=200,

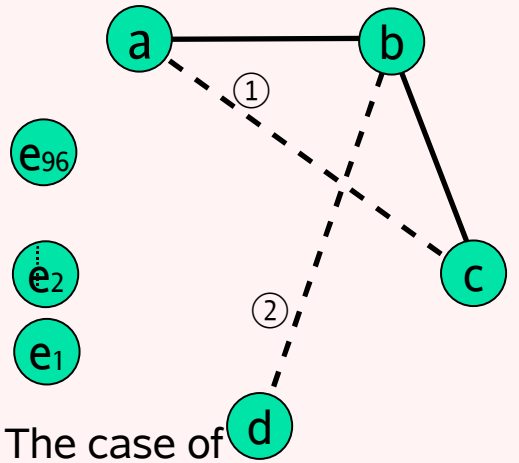
The mechanism with PageRank

- Characteristic candidate edges:
  - 1) between two nodes 2) node to isolated node 3) between two isolated nodes
- When the PageRank adopts agent's utility:
  - The ratio of transition from the isolated node is out: 100% and in: 15%
  - When a node connects to existing network, its node get higher postion.
  - An isolated nodes' position are decreased by the decrease of the number of isolation nodes.



	a	b	c	d	e	score
初期値	(1.17)	(2.21)	(1.17)	(0.23)	(0.23)	
①	1(1.52)	0(1.52)	0(1.51)	0(0.23)	1(0.23)	2
②	0(0.85)	1(1.56)	1(1.56)	1(0.85)	0(0.18)	3

	a	b	c	d	e_1	e_2	・・・	E96	score
初期値	(4.39)	(8.32)	(4.39)	(0.85)	(0.85)	(0.85)	・・・	(0.85)	
①	1(5.70)	0(5.70)	0(5.70)	0(0.85)	1(0.85)	1(0.85)	・・・	1(0.85)	97
②	0(3.81)	1(7.06)	1(7.06)	1(3.81)	0(0.82)	0(0.82)	・・・	0(0.82)	3



The case of numerous isolated nodes