KAIST CULTURE TECHNOLOGY

Collective Dynamics of 'Small-world' Networks

Watts, D., Strogatz, S. (1998). *Nature* 393, 440-442.

Seongchan Park

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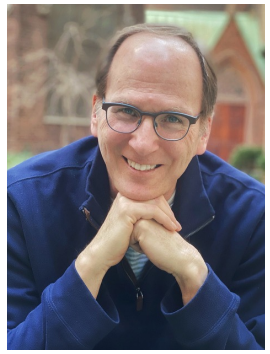
INDEX

01 Introduction

1) Authors & Paper

Authors



I think I've been contacted by someone from just about **every field**.

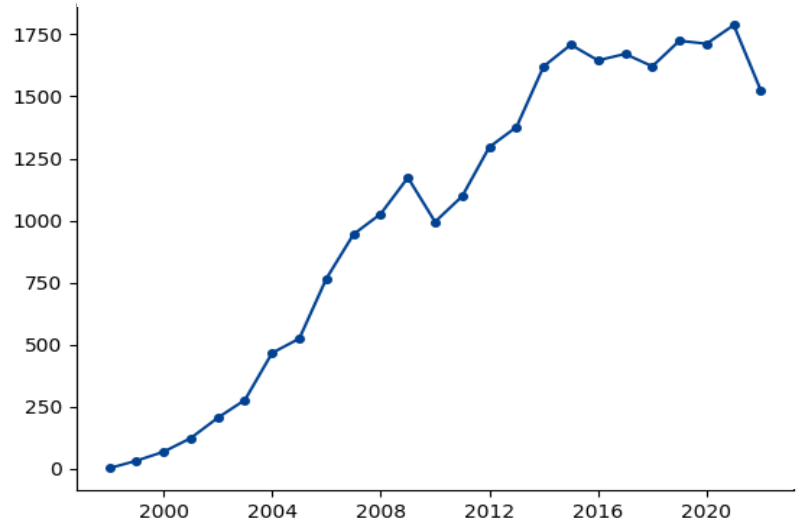
Duncan J. Watts

- Ph.D in Theoretical and Applied Mechanics (Advisor Steven Strogatz)
- Penn Integrates Knowledge University Professor at the University of Pennsylvania (CSS Lab)

Steven Strogatz

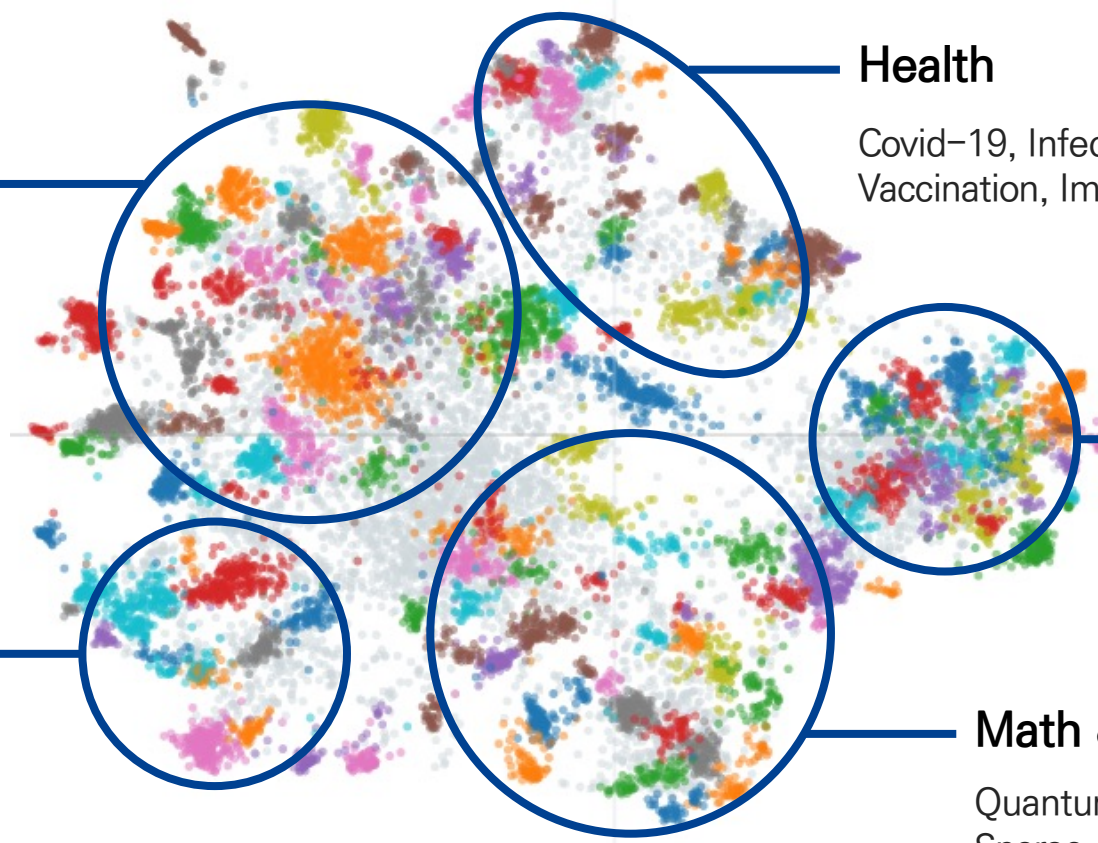
- Ph.D in Applied Mathematics
- Distinguished Professor for the Public Understanding of Science and Mathematics at the Cornell University

〈 Yearly Citation Trends for This Paper 〉



01 Introduction

1) Authors & Paper



Health

Covid-19, Infectious, Contagion, Obesity,
Vaccination, Immunization, Smoking

Social

Twitter, Community, Opinion, Node,
Centrality, Rumor, Voter, Market

Neuroscience

Neural, Alzheimer, Schizophrenia,
Disorder, Depression, Connectome

Infrastructure

Traffic, Road, Rail, Transportation
Power, Grid, Earthquake, Seismicity

Math & Physics

Quantum, Lattices, Graph, Edge,
Sparse, Gaussian, Boolean, Markovian

〈 BERTopic Results Based on Papers Citing This Paper (n=21,705) 〉

02 Network

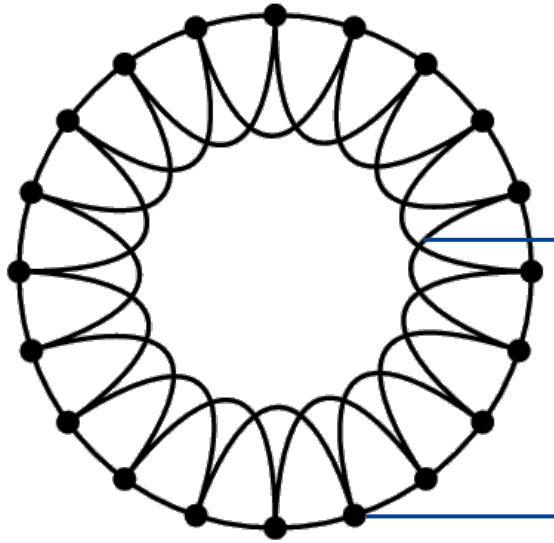
1) Regular & Random Network

〈 Regular Network 〉

$n = 20$

$k = 4$

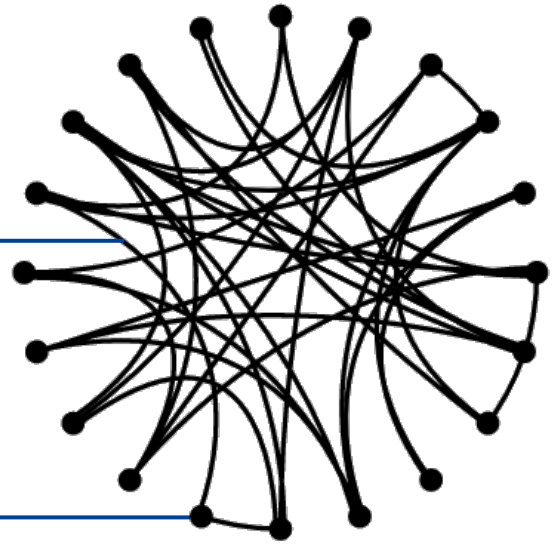
$\boldsymbol{p = 0}$



Edge

Vertex (Node)

〈 Random Network 〉



$n = 20$

$k = 4$

$\boldsymbol{p = 1}$

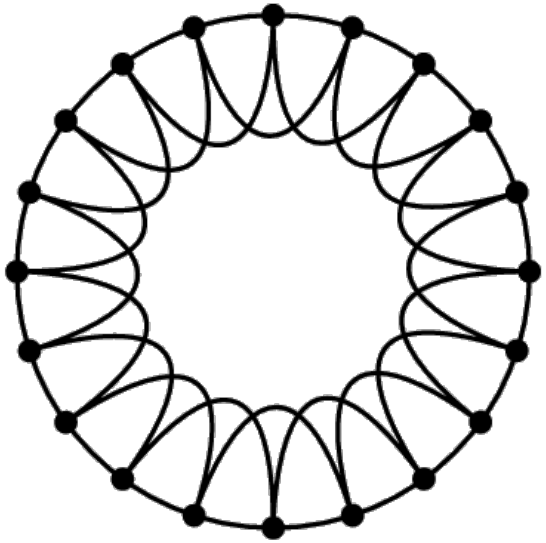
$n = Number\ of\ Vertices, \quad k = Number\ of\ Edges\ \ per\ Vertex$

$p = Probability\ of\ Rewire\ Each\ Edge\ at\ Random\ (0 < p < 1)$

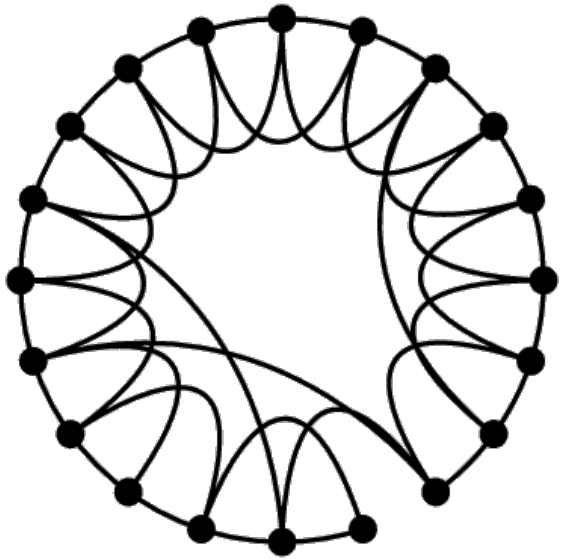
02 Network

2) Small-world Network

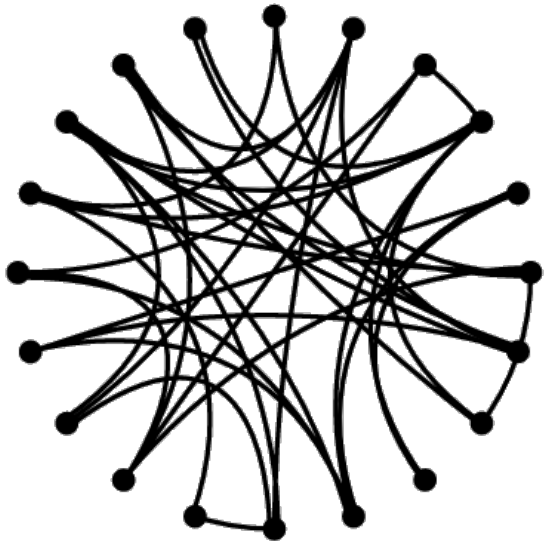
〈 Regular Network 〉



〈 Small-world Network 〉



〈 Random Network 〉



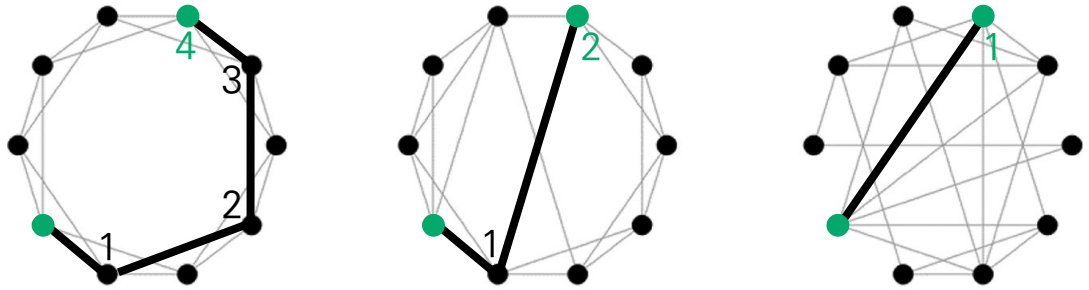
$p = 0$ ——— Increasing Randomness (Disorder) ⟶ $p = 1$

02 Network

3) Characteristics (L, C)

Mean Path Length (Global)

- Typical separation between two vertices
- Average of steps along the shortest paths for all possible pairs of network nodes
- How separate are the nodes in the network

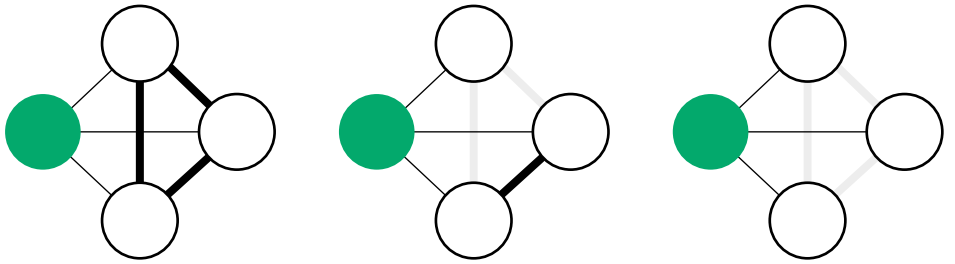


〈 Regular Network 〉 〈 Small-world Network 〉 〈 Random Network 〉

Long → Short

Clustering Coefficient (Local)

- Cliquishness of a typical neighborhood
- Cliquishness: No matter which node you choose, all nodes are connected to each other
- How many strong tie in the network



3/3 = 1 1/3 0/3 = 0

High → Low

02 Network

3) Characteristics (L, C)

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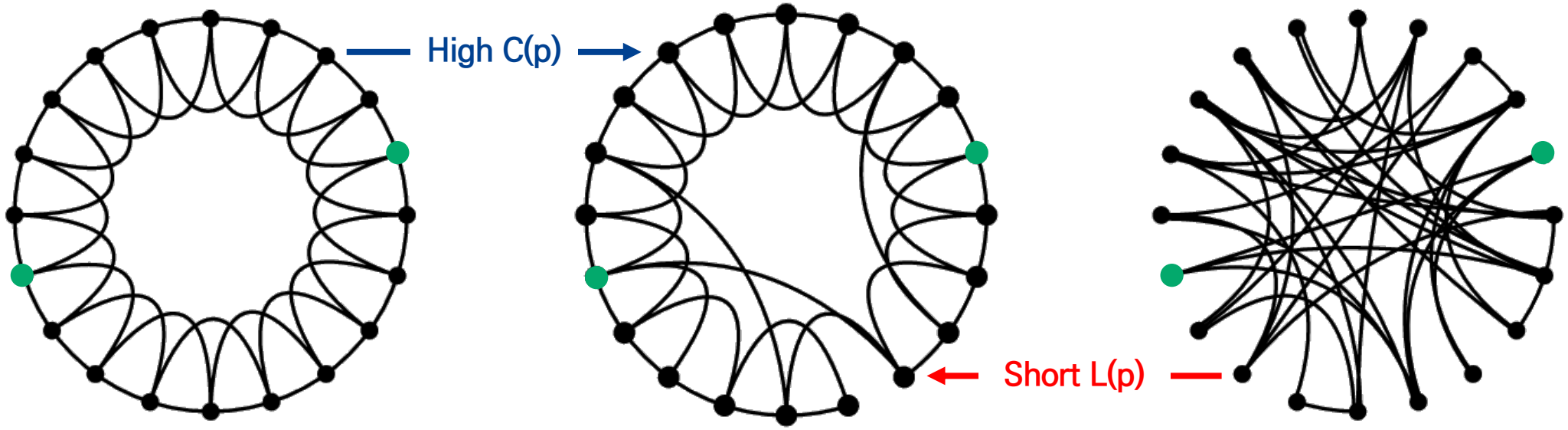
〈 Regular Network 〉 〈 Small-world Network 〉 〈 Random Network 〉



Length = L(p): Long

Clustering = C(p): High

Length = L(p): Short

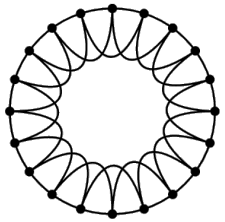
Clustering = C(p): High

Length = L(p): Short

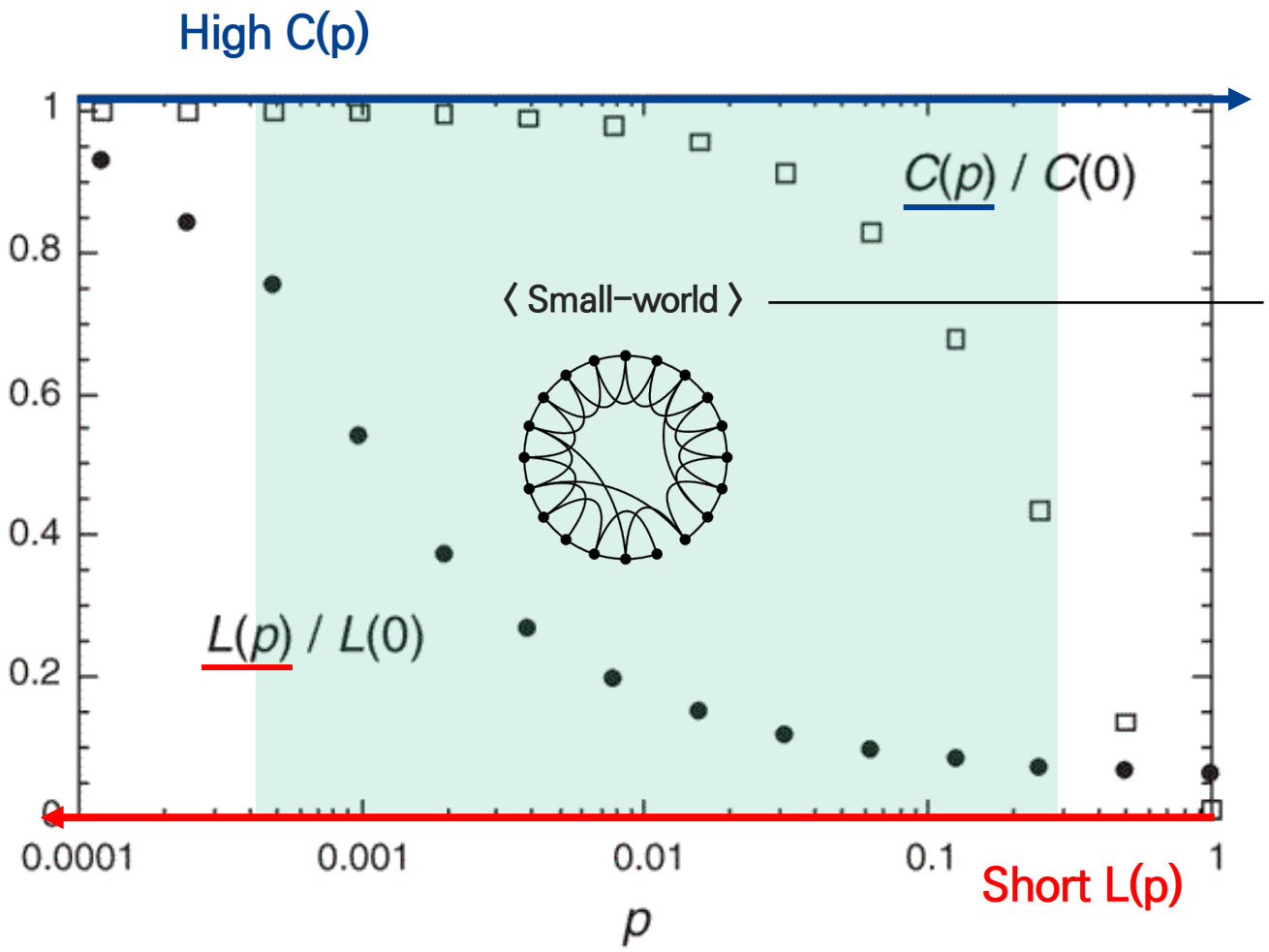
Clustering = C(p): Low

02 Network

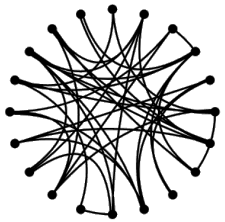
3) Characteristics (L, C)



〈 Regular 〉



Random connections make it easier to reach other nodes



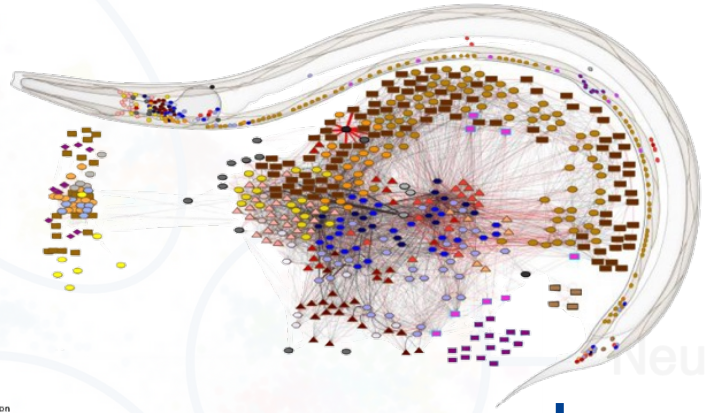
〈 Random 〉

03 Examples

1) Three Empirical Examples

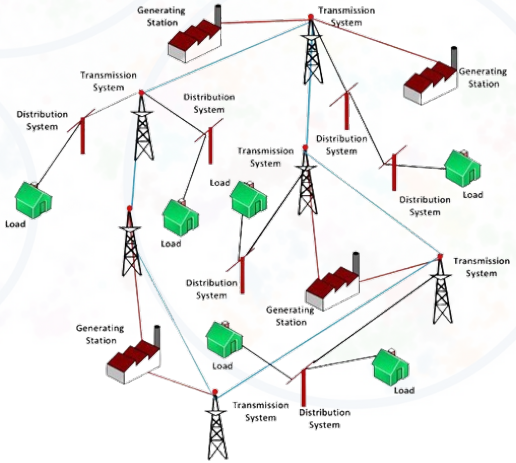
① Actors Network

Surrogate for a social network



② Power Grid Network

Relevant to the efficiency and robustness



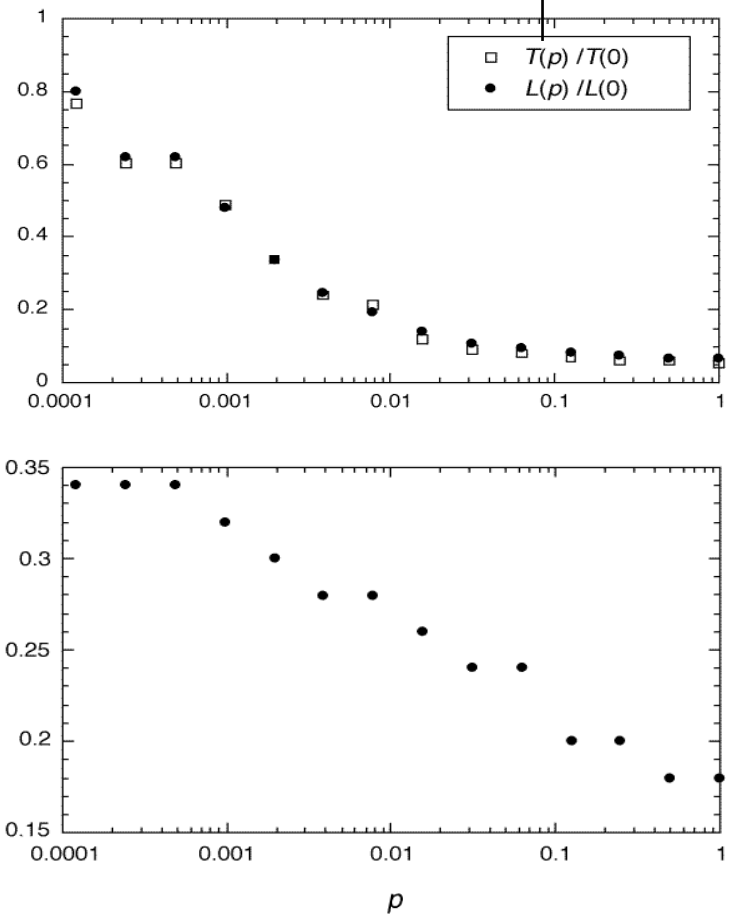
③ C. Elegans Network

Sole example of a completely mapped neural network

03 Examples

2) Infectious Disease (Functional Significance of Small-world Network)

Time which takes for everyone in the network to be infected



Time T(p) required for global infection resembles the L(p) curve

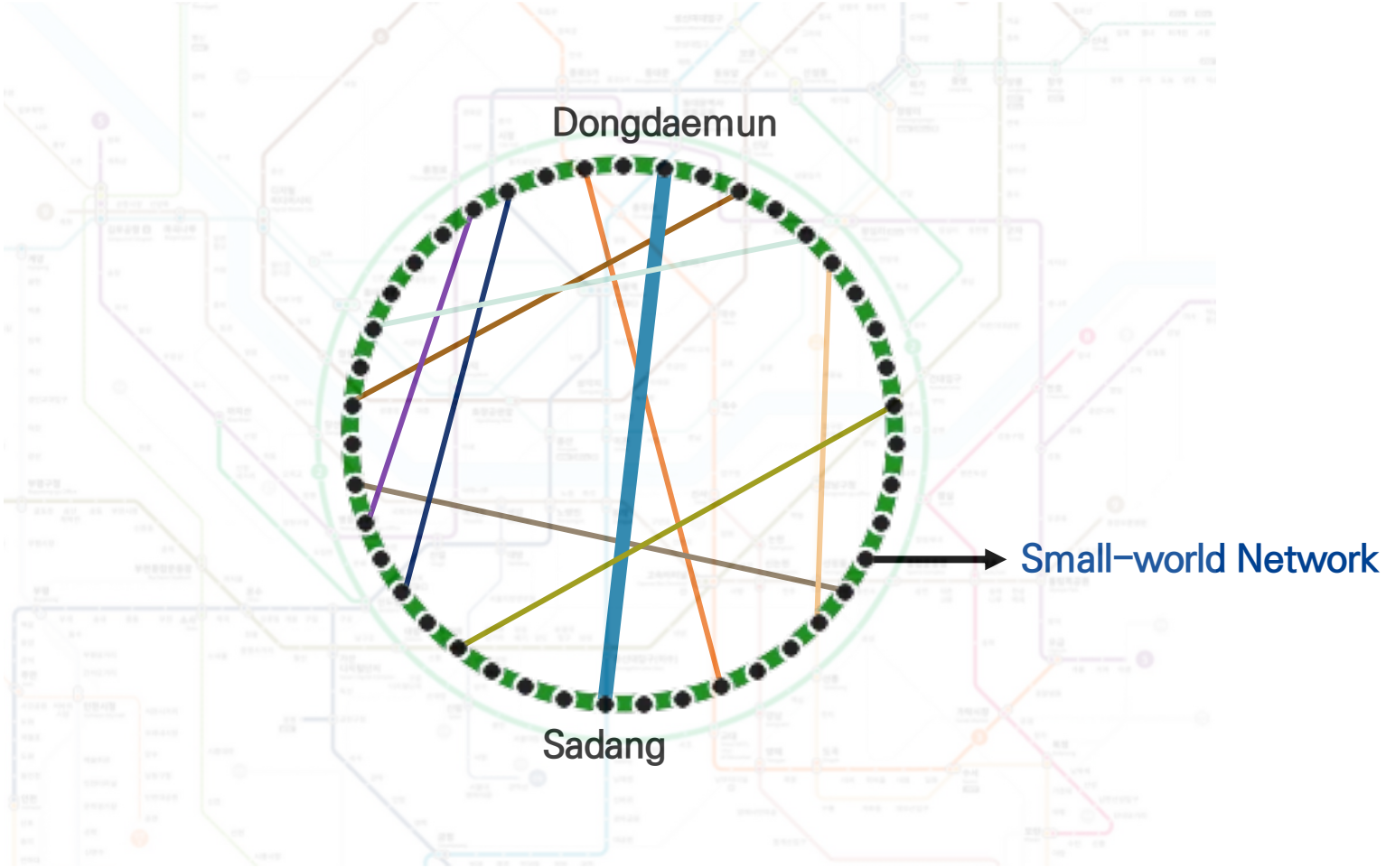
Critical infectiousness at which the disease infects half the population — r_{half}

r_{half} decreases rapidly for small p

〈 Simulation Results for Simple Model of Disease Spreading 〉

04 Summary

1) Significance of Small-world Network

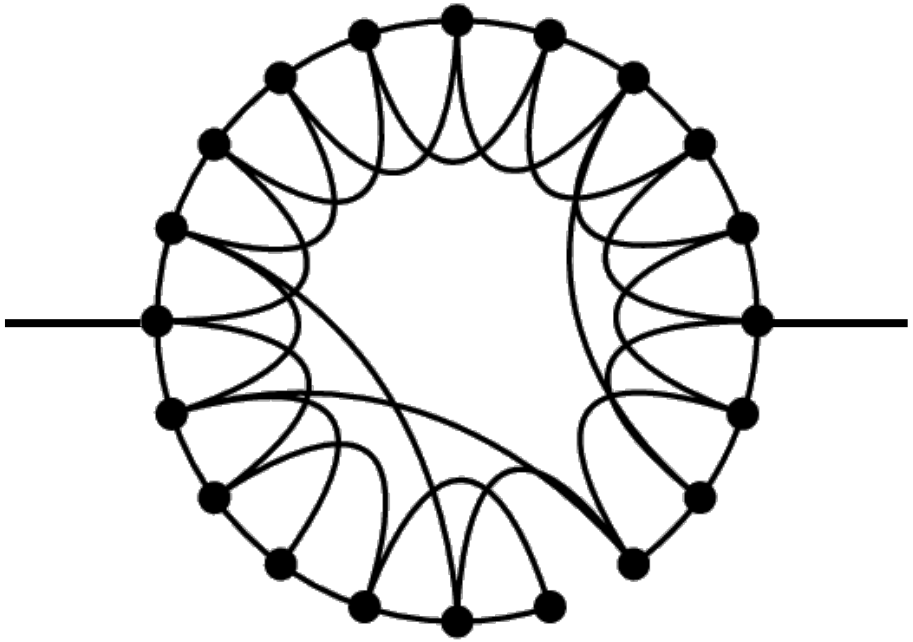


〈 Seoul Metro as 'Small-world Network' Analogical Example 〉

04 Summary

1) Significance of Small-world Network

High Clustering



Short Length

〈 Small-world Network 〉 ⟶ Prevalent in various fields in our real world

“ Connectivity, Efficiency, Infectivity ”