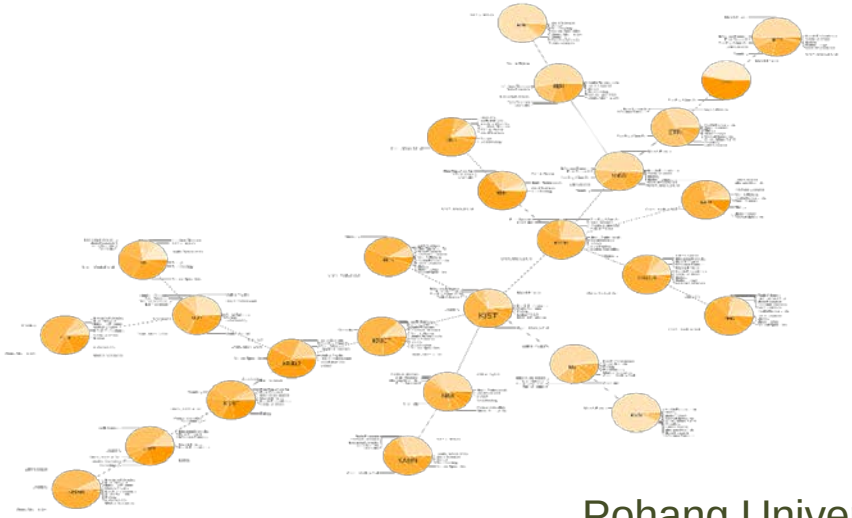
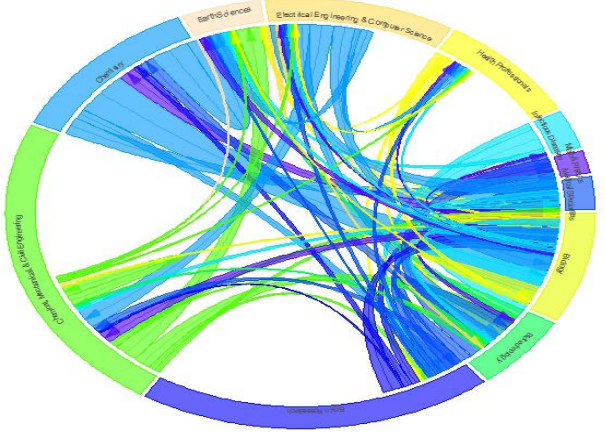
APCTP
Asia Pacific Center for Theoretical Physics

POSTECH
POHANG UNIVERSITY OF SCIENCE AND TECHNOLOGY
포항공과대학교

Complexity Analysis of Social System - Transportation and Bibliometrics





Woo-Sung Jung
Pohang University of Science and Technology (POSTECH)
wsjung@postech.ac.kr

ABOUT the APCTP

- Purpose of Foundation
  - Devotion to foundational issues in theoretical physics at the highest levels of the regional excellence
- Mission
  - As an international organization in the field of theoreti cal physics, we aim to lead basic science in the region. As such, the APCTP plays a key role:

    In creating a basic research hub while enhancing global leadership capability.

    In providing an academic platform for theoretical physics community in the Asia Pacific region.

Policy Commissioner Top

Name	Affiliation	Term
Woo-Sung JUNG	POSTECH	Feb. 12, 2015 ~ Feb. 11, 2017

Milestones (1)

1993. 02	Formation of the International Planning Committee (IPC)
1994. 05	IPC recommends Korea as the host of the APCTP
11	Association for Science Cooperation in Asia (ASCA) endorses the proposal to host the APCTP in Korea
1995. 09	UNESCO PAC, IUPAP and AAPPS endorse the proposal for the APCTP
1996. 06	Inauguration Conference and establishment of the APCTP
1997. 01	The Board appoints Prof C. N. Yang (1957 Nobel Laureate for Physics) as the 1st President and Chairperson

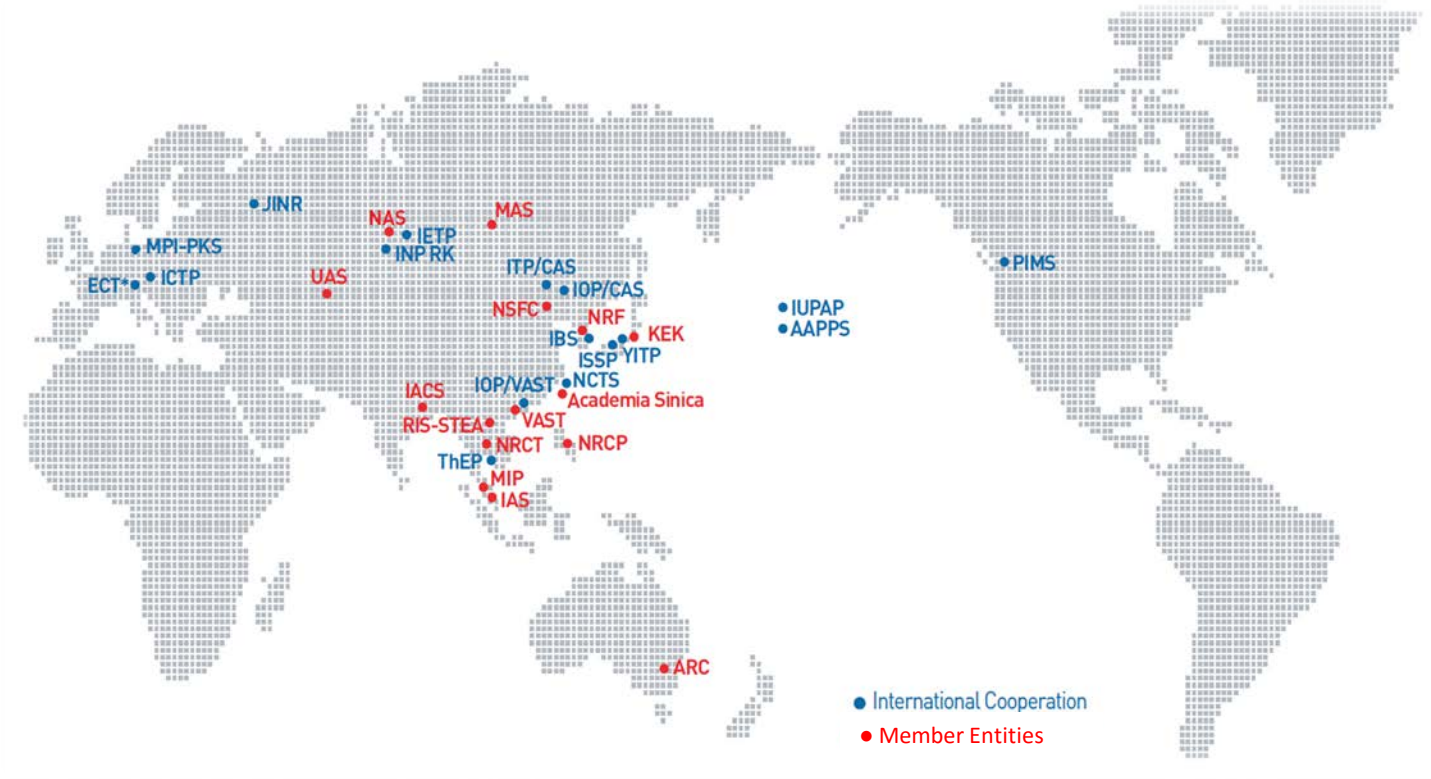
Asia-Pacific Economic Cooperation

APCTP
Asia Pacific Center for Theoretical Physics

Milestones (2)

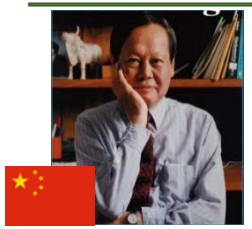
2001. 01	Activity-Financing Contract between UNESCO and the APCTP
2006. 11	APCTP 10th Anniversary Ceremony Lao PDR and Mongolia become new members
2008. 03	India becomes a new member
2011. 04	Uzbekistan becomes a new member
2013. 11	Kazakhstan becomes a new member
2016. 6	Canada becomes a new member

STATUS OF INTERNATIONAL COOPERATION



Leadership

President



Chen-Ning YANG

1997~ 2000

Nobel Laureate in Physics, 1957

Robert B. LAUGHLIN

2004~ 2007

Nobel Laureate in Physics, 1988

Peter FULDE

2007~ 2013

Emeritus Director of MPI-PKS

Seunghwan KIM

2013~ 2014

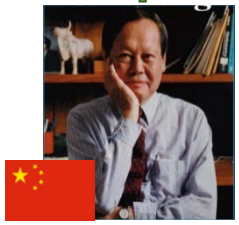
President of KOFAC

Bum-Hoon LEE

2015~ Present

Physics Prof. of Sogang Univ.

Chairperson



Chen-Ning YANG

1997~ 2000

Nobel Laureate in Physics, 1957

A. ARIMA

2001~ 2005

Former Minister of Education, Culture Sports, Science and Technology

NGUYEN Van Hieu

2005~ 2010

Former President of NCST

Won NAMKUNG

2010~ 2013

Physics Prof. of POSTECH

Paul A. PEARCE

2013~ Present

Physics Prof. of Univ. of Melbourne

What APCTP does

Research Programs

- Junior Research Groups (JRG)
- Young Scientist Training Program (YST)
- Visitors Program

Scientific Activities

- Academic Programs
- Focus Research Programs

Physics Outreach Program

- Web Journal : Crossroads
- Science Communication School, etc.

Complexity in Social System Group

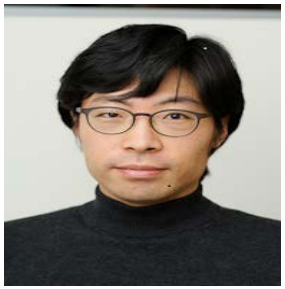
- Department of Physics
- Department of Industrial and Management Engineering (Graduate School of Technology and Innovation Management)

- Physics → expanding

- What physicists do

- Understading Nature (Social Phenomena) w/ physicist's view and theory
- Introducing the theory and research tool to other fields

Complexity in Social System Group



Hang-Hyun Jo
Research Professor
(Physics)

Min-Woo Ahn
(Physics)

Byung Hwa Lee
(Physics)

Inho Hong
(Physics)

Teakho You
(Industrial & Management Engineering)

Jeongjun Kim
(Physics)

Hyunuk Kim
(IME)

Jisung Yun
(IME)

Minji Kwon
(IME)

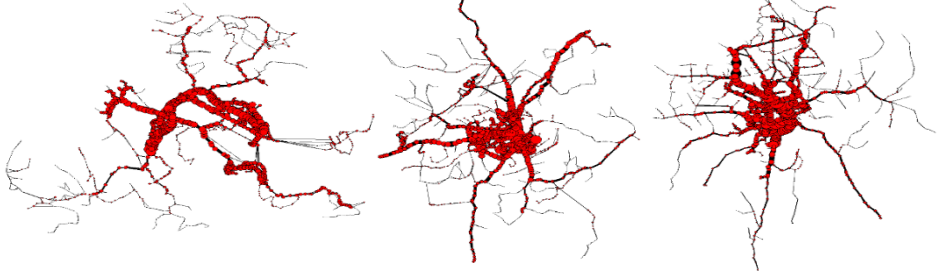
Min-Young Lee
(Physics)

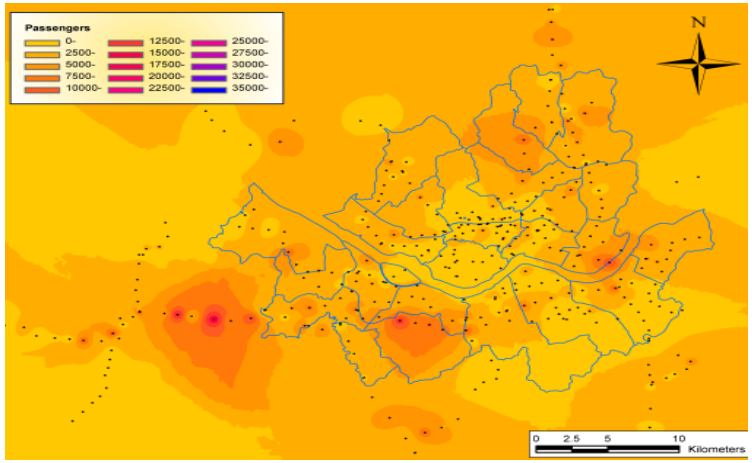
http://complex.postech.ac.kr

Topics

- Transportation System

A. Changwon B. Cheongju C. Jeonju

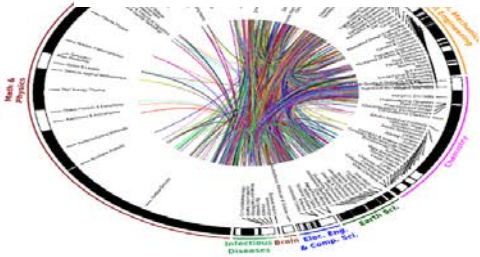




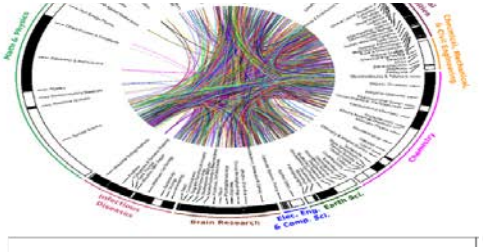
- Bibliographic Data

Korea

USA
(National Lab)



Germany
(Max Planck)



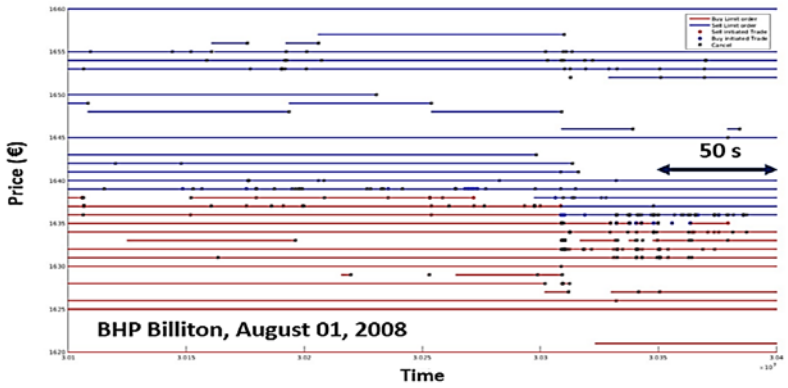
Topics

- Econophysics

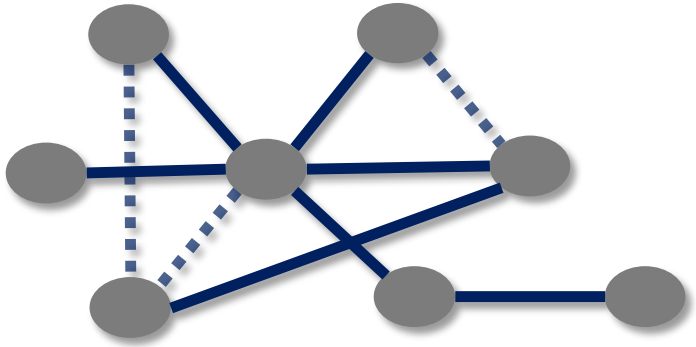
VOD.L VODAFONE GROUP PLC ORD USD0.11 3/7

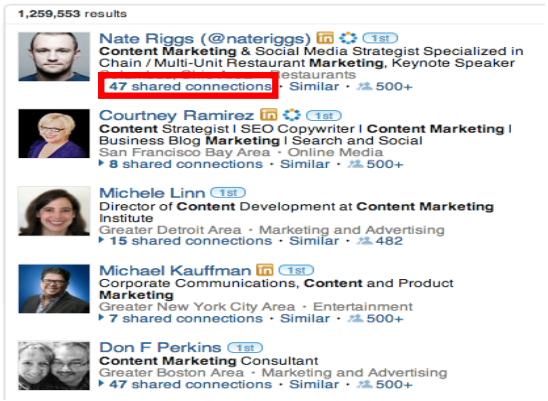
Order Book VOD.L

4		71006	162.9 - 162.95	79959		9
261		6,825,863	155.42523 - 167.88226	7,839,197		432
Cumul	Maker	Size	Bid	Ask	Size	Maker	Cumul
4		71006	162.90	162.95	79959		9
10		110436	162.85	163.00	165547		11
11		194292	162.80	163.05	95435		15
14		165796	162.75	163.10	246286		18
16		319872	162.70	163.15	237244		14
10		224002	162.65	163.20	229145		13
7		163907	162.60	163.25	304053		13
4		108296	162.55	163.30	266717		13
3		90365	162.50	163.35	169815		8
25		165282	162.45	163.40	177534		7
1		30702	162.40	163.45	173809		5



- Network & Social Media



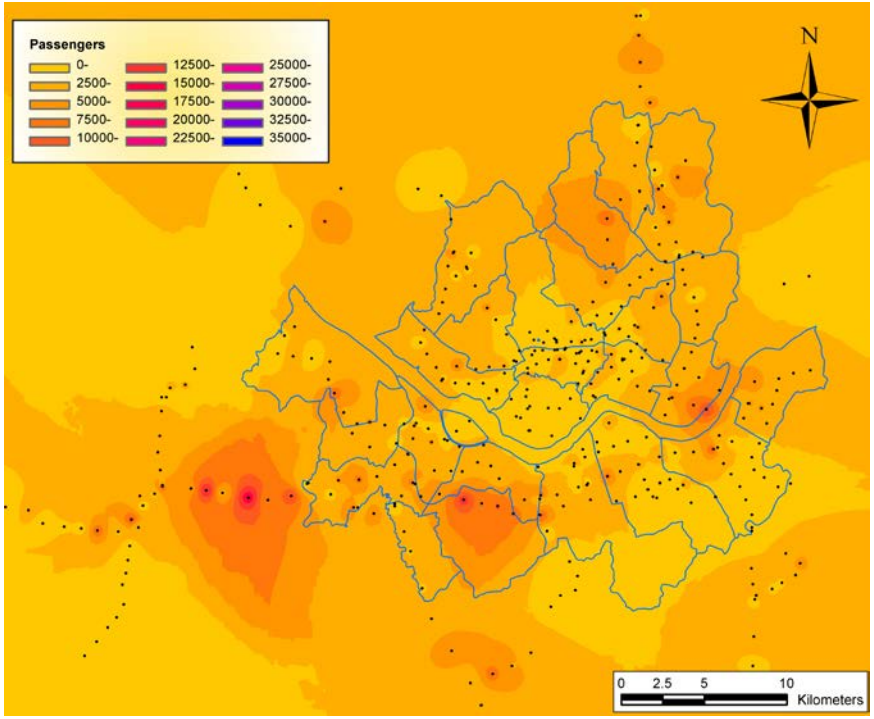


Subway & Highway

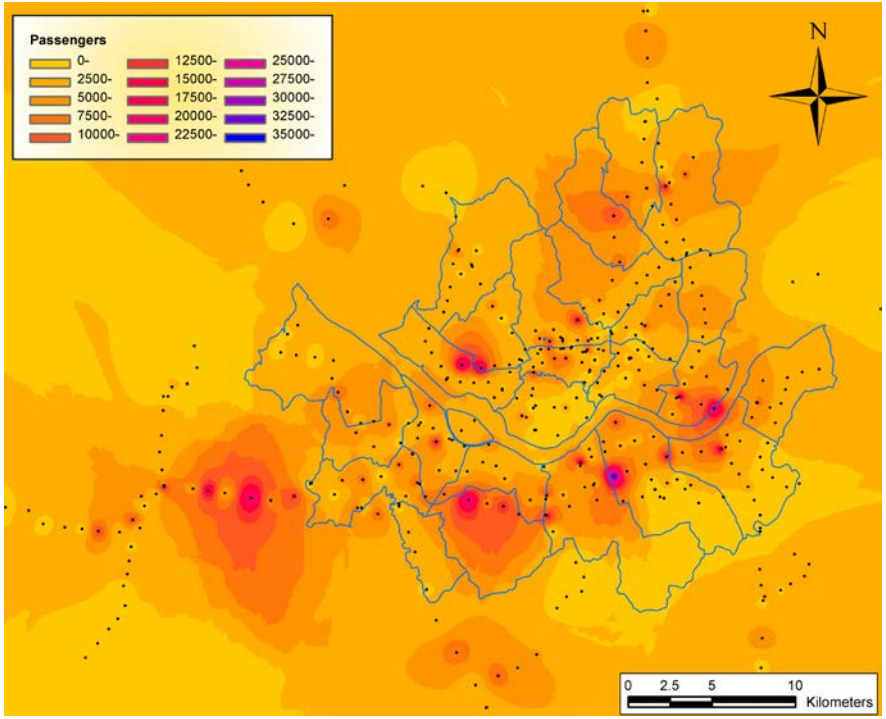
I know what you did last night

- Metropolitan Seoul public transportation system: subway+bus
  - Smart Card
  - Time/position information
- 10,000,000+ transaction/day
- Big brother tracks the movements of individuals
  - departure/arrival station, travel time…
- Human mobility analysis

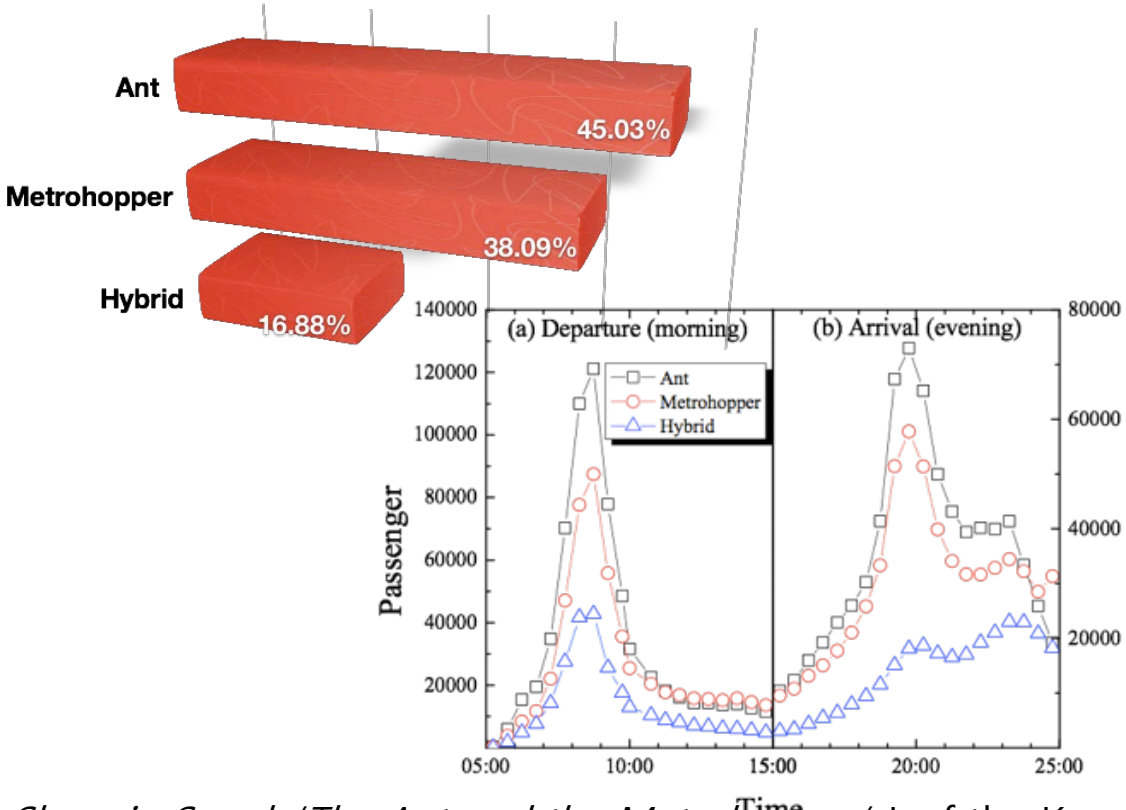
Spatial distribution
(departures in the morning)



Spatial distribution
(arrivals in the evening)



Ant and Metrohopper



* *Sleep in Seoul: 'The Ant and the Metrohopper',* J. of the Korean Physical Society **57**(4), 823 (2010)

Network structure

	network distance	physical distance
N	380	←
L	20.0	27.9 km
$n_{\max}$	62	139 km
C^*	6.41×10^{-3}	←
D	62	139 km
R	31	69.8 km
E	7.86×10^{-2}	0.747

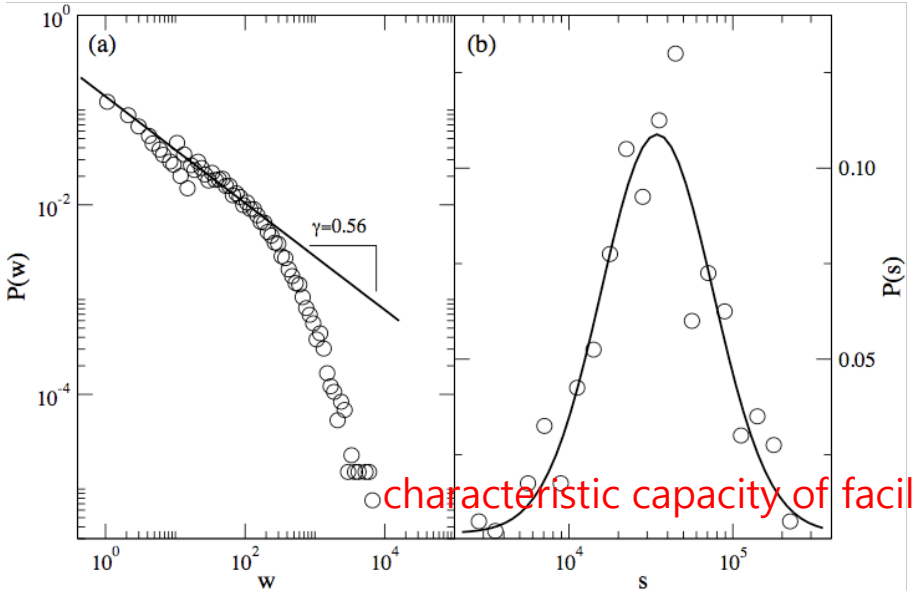
- L: characteristic path length
- C*: clustering coefficient
- D: diameter
- R: radius
- E: network efficiency
  - ideal case: all connected network

$$\varepsilon = \frac{1}{N(N-1)} \sum_{i \neq j} \frac{1}{n_{ij}}$$

* *Statistical analysis of the Metropolitan Seoul Subway System*, Physica A **387**, 6231 (2008)

Weight/Strength

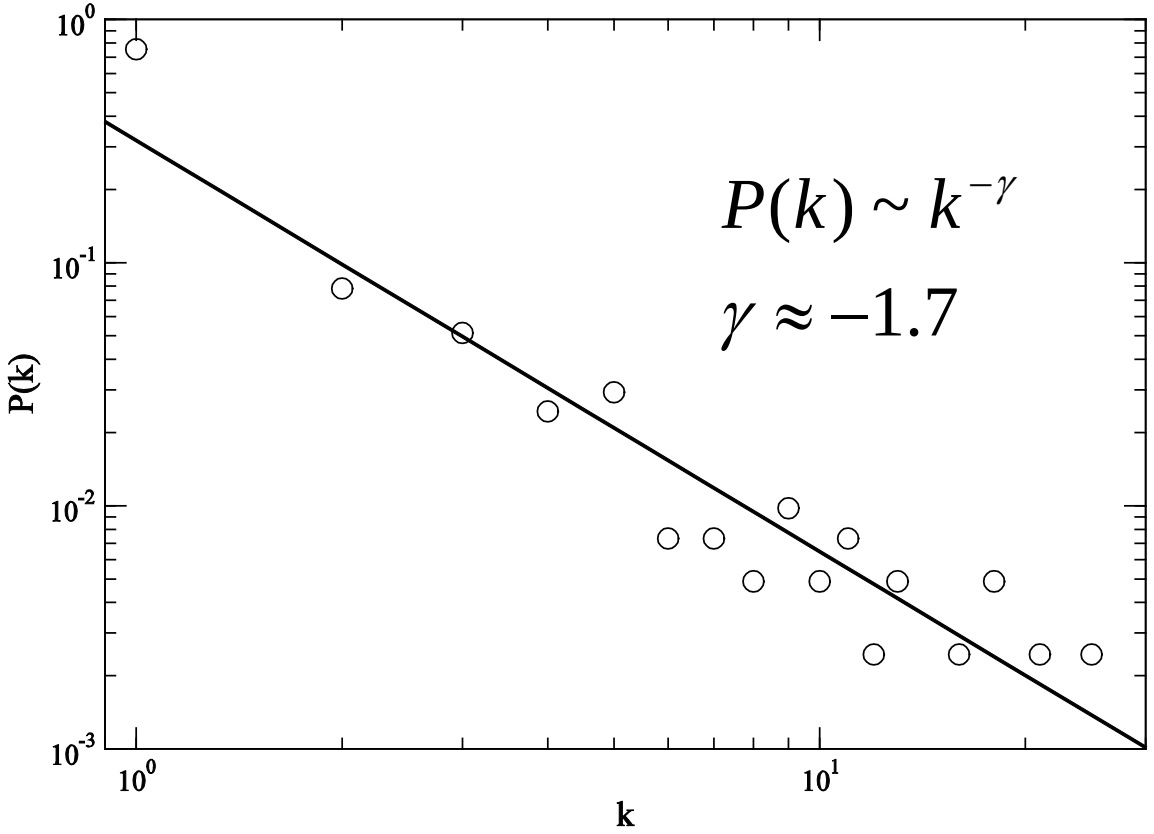
- Weight: traffic flows between stops
- Strength: incoming and outgoing flows of a given stop



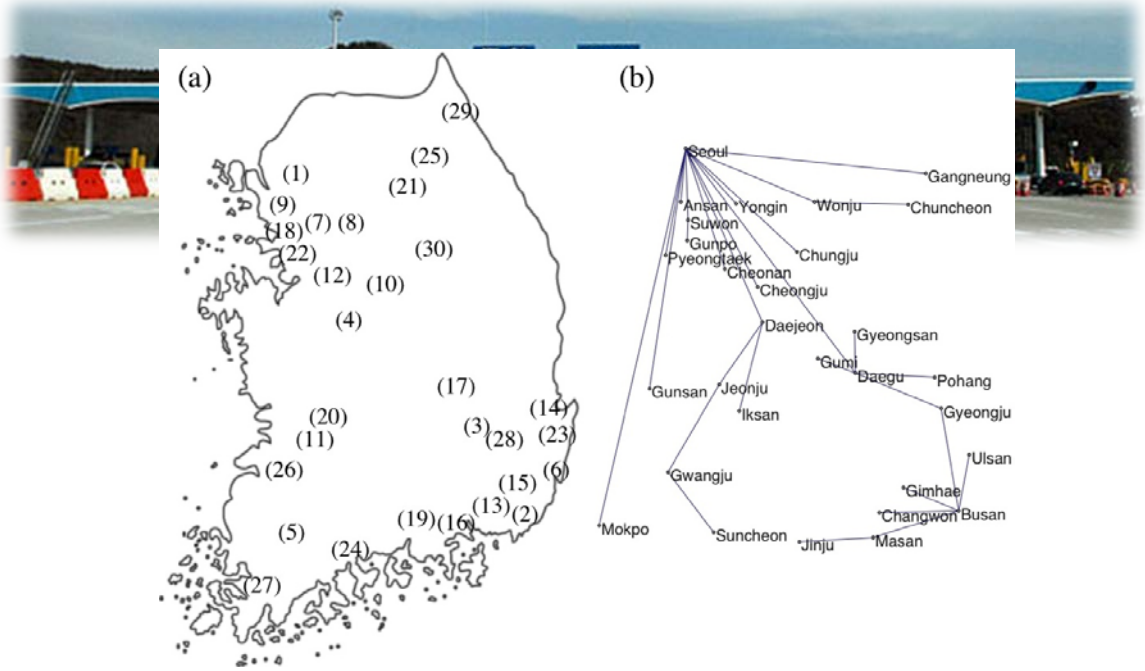
MST


Cheonho
Gwanghwamun
Hwagok
Euljiro-1ga
Cheongdam
Nowon
Sangbong
Anguk
Gongdeok
Yeonsinnae
Hwajeong
Apgujeong
Express Bus Terminal
Gangnam
Seohyeon
Suyu
Jonggak
Yeongdeungpo
Bupyeong
Incheon Bus Terminal
Suwon
Beomgye

Degree distribution

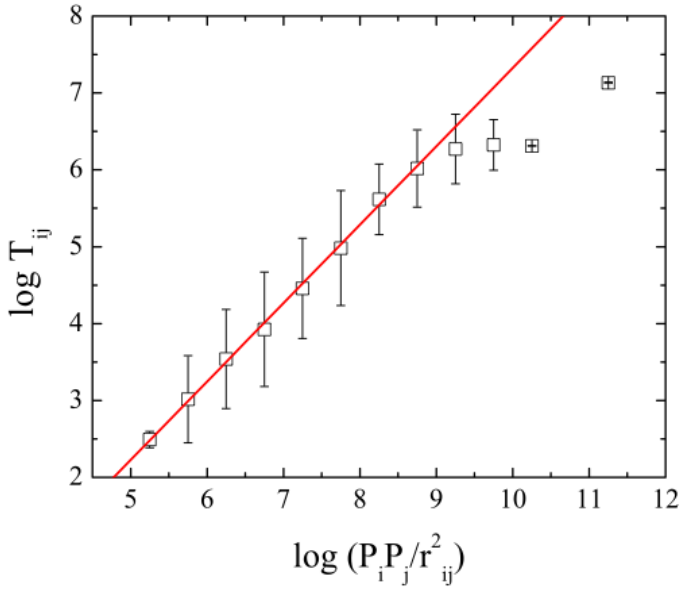


Korean highway system



•*Gravity model in the Korean highway*, Europhysics Letters **81**, 48005 (2008)

Gravity Model

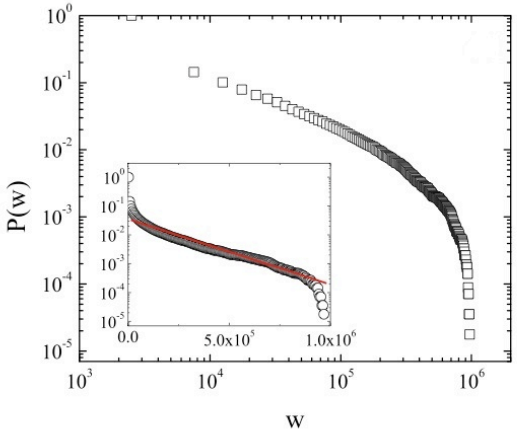


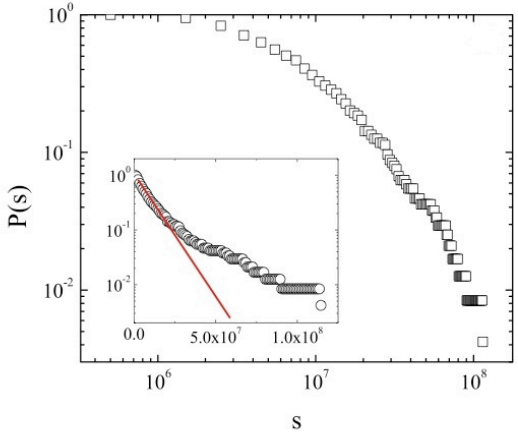
$$T_{ij} \sim \frac{P_i P_j}{r_{ij}^2}$$

- Centralization
  Greater Seoul: More centralized

Weight/Strength

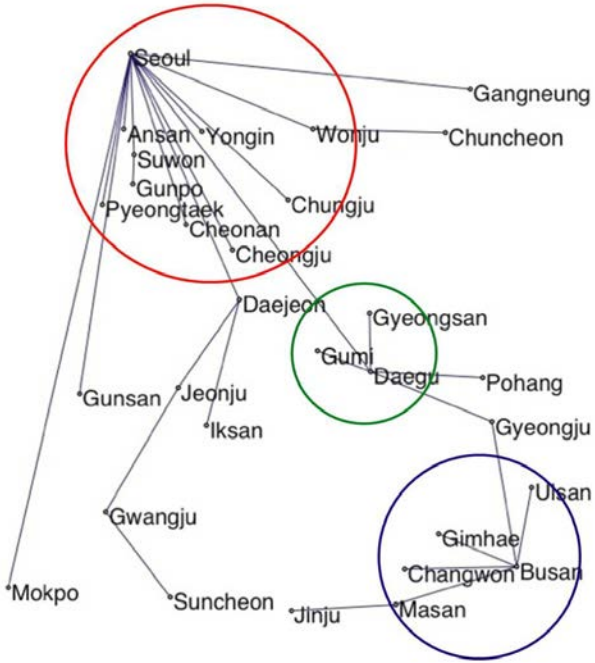
- Weight: traffic flows between cities
- Strength: incoming and outgoing flows of a given city





Clustering - saparation

1	Seoul	11	Hwawon
2	West Seoul	12	North Daegu
3	East Seoul	13	Busan
4	Gunja	14	Jangyu
5	North Busan	15	North Suwon
6	West Daegu	16	Cheonan
7	Suwon	17	Osan
8	West Busan	18	Daejeon
9	Daedong	19	East Daegu
10	East Suwon	20	East Gimhae



Sports-physics

PNAS

Quantitative and empirical demonstration of the Matthew effect in a study of career longevity

Alexander M. Petersen[a,1], Woo-Sung Jung[b,a], Jae-Suk Yang[c], and H. Eugene Stanley[a,1]

[a]Center for Polymer Studies and Department of Physics, Boston University, Boston, MA 02215; [b]Graduate Program for Technology and Innovation Management and Department of Physics, Pohang University of Science and Technology, Pohang 790-784, Republic of Korea; and [c]Sanford C. Benstein and Co. Center for Leadership and Ethics, Columbia Business School, Columbia University, New York, NY 10027

Contributed by H. Eugene Stanley, November 10, 2010 (sent for review November 8, 2009)

The Matthew effect refers to the adage written some two-thousand years ago in the Gospel of St. Matthew: "For to all those who have, more will be given." Even two millennia later, this idiom is used by sociologists to qualitatively describe the dynamics of individual progress and the interplay between status and reward. Quantitative studies of professional careers are traditionally lim-

(MLB), Korean Professional Baseball, the National Basketball Association (NBA), and the English Premier League.

Career longevity is a fundamental metric that influences the overall legacy of an employee because for most individuals the measure of success is intrinsically related, although not perfectly correlated, to his or her career length. Common experience in

Bibliometrics

Project members

Complexity in Social System Lab.

Woo-Sung Jung

Taekho You

Hyunuk Kim

STEPI

Hyeonchae Yang

Collaboration

+

Univ. of Oxford

Hyejin Youn

Santa Fe Institute

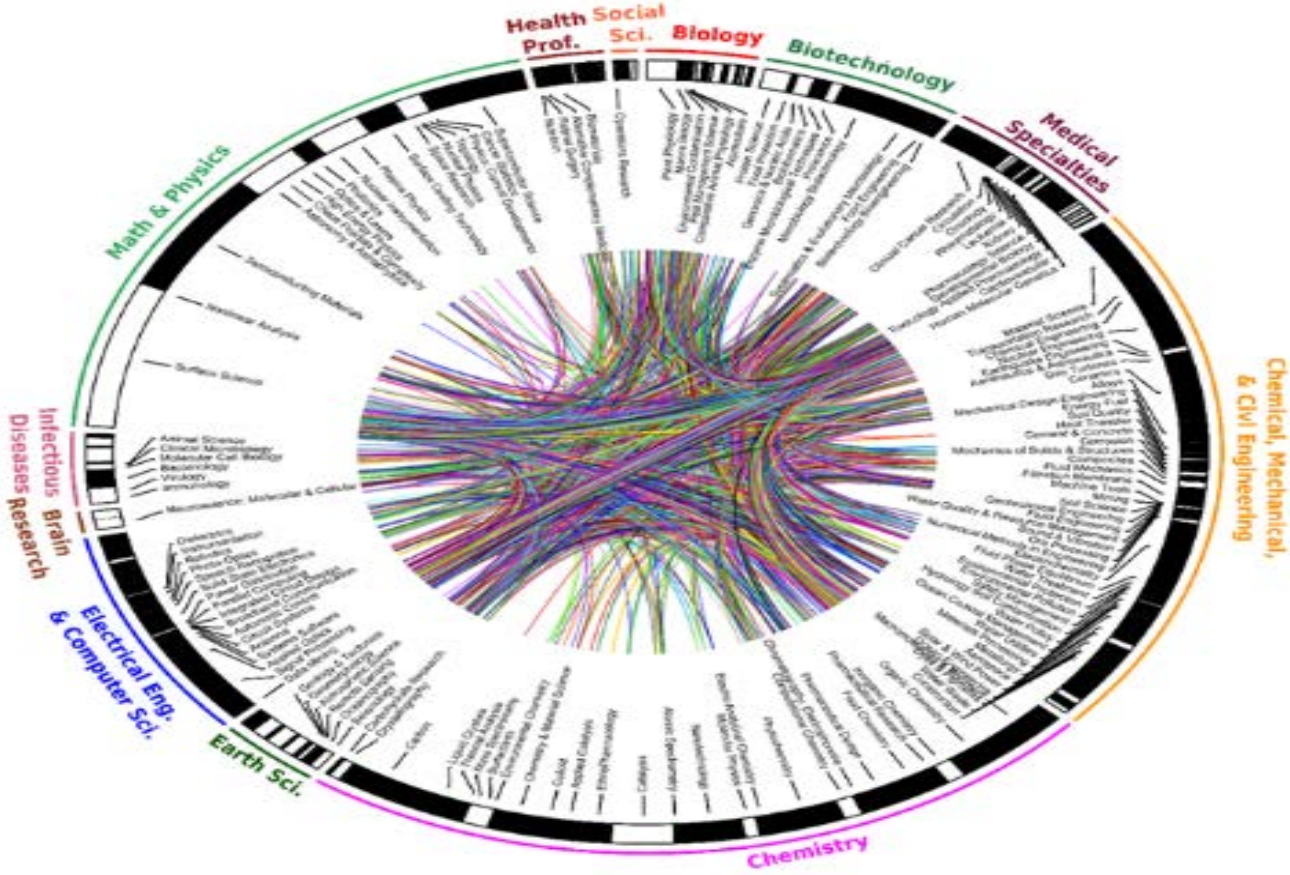
Marcus J. Hamilton

Korea Public Research Institute

- A strategic management approach for Korean public research institutes based on bibliometric investigation, Quality & Quantity 49, 1437-1464 (2015)

- Structural efficiency to manipulate public research institution networks, Technological Forecasting & Social Change, in press (2016)

Korea Data


Health Prof.
Social Sci.
Biology
Biotechnology
Medical Specialties
Chemical, Mechanical, & Civil Engineering
Chemistry
Earth Sci.
Electrical Eng. & Computer Sci.
Infectious Diseases
Brain Research
Math & Physics

Method

Study Population	Korean Government-funded research institutes (GRIs) ◦ 26 sub-organizations
Data Collection	Bibliographic data from Thomson Reuters Web of Knowledge ◦ 18 years (1995-2012) are divided into 6 periods (1 period = 3 yrs) ◦ 59,333 articles
Portfolio Identification	Journal title based classification system ◦ UCSD map of science ◦ 554 sub-disciplines within 13 disciplines
Conceptual Basis	Complex systems ◦ A large number of subparts that interact with each other, in so doing, produce novel patterns
Thematic Dependency	Temporal dependency between sub-disciplines ◦ Information-theoretic indicator, transfer-entropy ◦ Quantification of thematic causality in a portfolio
Organizational Dependency	Structural controllability of inter-organizational network ◦ Organizational network based on research similarity ◦ Extraction of change initiators to influence throughout network

Identification of Research Areas

- UCSD Map of Science
  - Distinguishable not only journal titles indexed in major database but keywords
  - Easy to identify disciplinary realm in coordinates and relations between fields
  - Available updates

- Journal-title based classification system: 554 sub-disciplines belonging to 13 disciplines (Web of Science)

Thematic Causality in Portfolio

Predictive Causality (Wiener 1956)

- "For two simultaneously measured signals, if we can predict the first signal better by using the past information from the second one than by using the information without it, then we call the second signal causal to the first one."
- NOTE: not necessarily imply common causality

Transfer Entropy (Schreiber 2000)

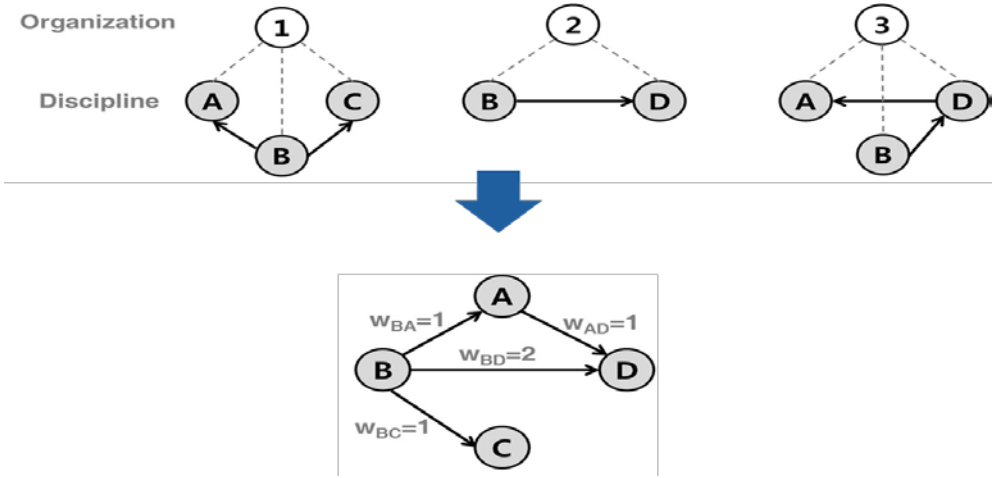
- Indicator for predictive causality in information-theory
- Information transfer from X to Y

$$TE(X \rightarrow Y) = H(y_{t+1}|y_t^n) - H(y_{t+1}|y_t^n, x_t^m)$$

  - X, Y: Two concurrently time series
  - Past values: $x_t^m = \{x_t, \cdots, x_{t-m+1}\}, y_t^n = \{y_t, \cdots, y_{t-n+1}\}$
  - Reduction of uncertainty in y_{t+1} given y_t^n and x_t^m rather than given sole condition y_t^n

Thematic Causality Network

- Aggregation of subordinate thematic relations



- To increase efficiency in analysis of bipartite network
- Node:
  sub-disciplines
- Links:
  causal relations
- Weights:
  no. of appearances

Inter-organizational Network

Disciplinary Weighting for Portfolio

- Inverse frequency approach
  (García, Rodríguez-Sánchez et al. 2012)
- Weight of sub-discipline *m* for representing research output of institute *i*

$$w_{m,i} = freq_{mi} \times \log(\frac{N}{n_m})$$

  - $freq_{mi}$: number of papers published in sub-discipline *m* at institute *i*
  - N: number of institutes
  - n_m: number of institutes that published in sub-discipline *m*

Portfolio Similarity

- Second-order cosine similarities
  (Colliander and Ahlgren 2012)

Structural Controllability

Controllability of Complex Network (Yuan et al. 2013)

- Combining control theory and network science
- A network system is controllable by imposing external signals on a subset of its nodes, system can be effectively driven from any initial state to desired final state in finite time

Network G(A): $\dot{x}(t) = Ax(t)$

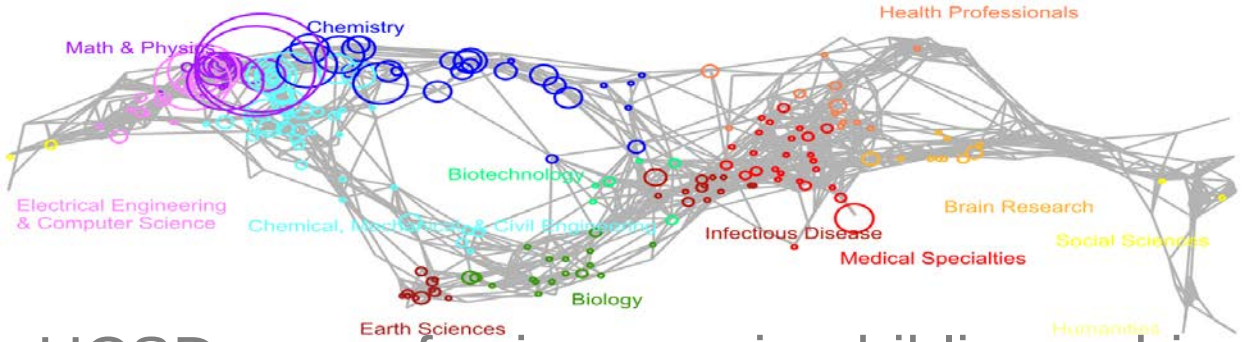
- linear time-invariant model
- Vector $x \in \mathbb{R}^N$: state of nodes at time t
- A $\in \mathbb{R}^{N \times N}$: portfolio similarity matrix
  - a_{ij}: research similairty between institute i to institute j

Controlled network G(A, B): $\dot{x}(t) = Ax(t) + Bu(t)$

- Adding m controllers by ordinary differential equations
  - Vector u(t) $\in \mathbb{R}^m$: controller, input vector
  - B $\in \mathbb{R}^{N \times m}$: control matrix
- When controllability matrix (C) has full rank, system is controllable
  - $C = (B, AB, A^2B, \cdots A^{N-1}B)$

Portfolio Identification

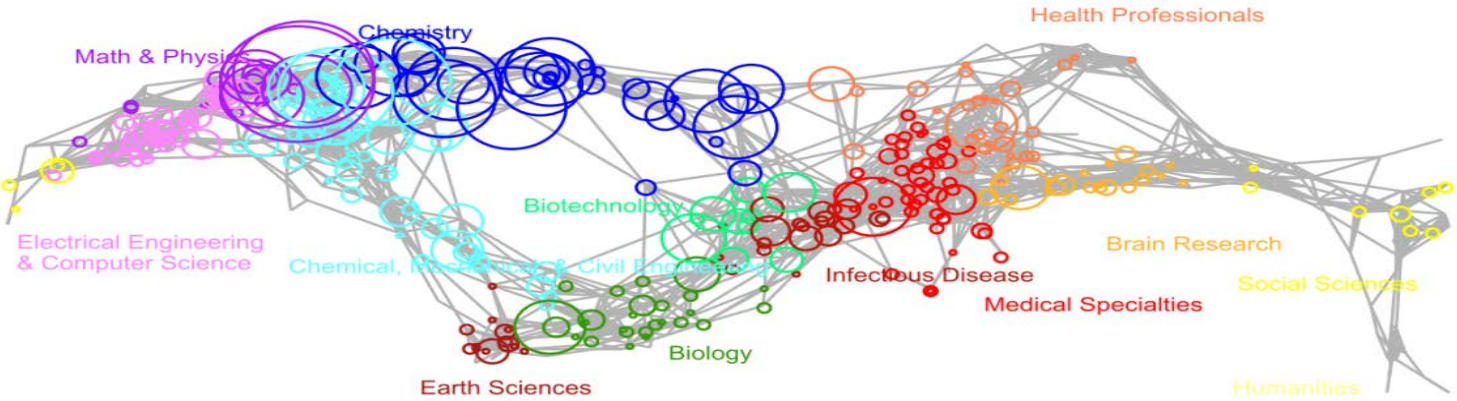
- Example of KRISS
  (Korea Research Institute of Standards and Science, 1995-2012)



- UCSD map of science using bibliographic data
- 554 sub-disciplines and 13 disciplines
- Divided into 6 periods (1 period = 3 years)

Portfolio Identification

- Example of KIST
  (Korea Institute of Science and Technology, 1995-2012)



Major Research Areas

- Frequently Appearing Sub-disciplines in Portfolios: Mutually Interesting Areas
  - Math and Physics > Surface Science (13 times)
  - Chemical, Mechanical, and Civil Engineering > Ceramics and Material Science (11 times)
    Chemistry > Nanotechnology (11 times)
    Math and Physics > Semiconducting Materials (11 times)

- Overall GRIs' Commitment vs International Attention to Each Area
  - Relative significances of fraction in GRIs and UCSD map at sub-discipline levels
  - One-tailed z-test to statistically compare two proportions (p-value<0.01)

Major Research Areas

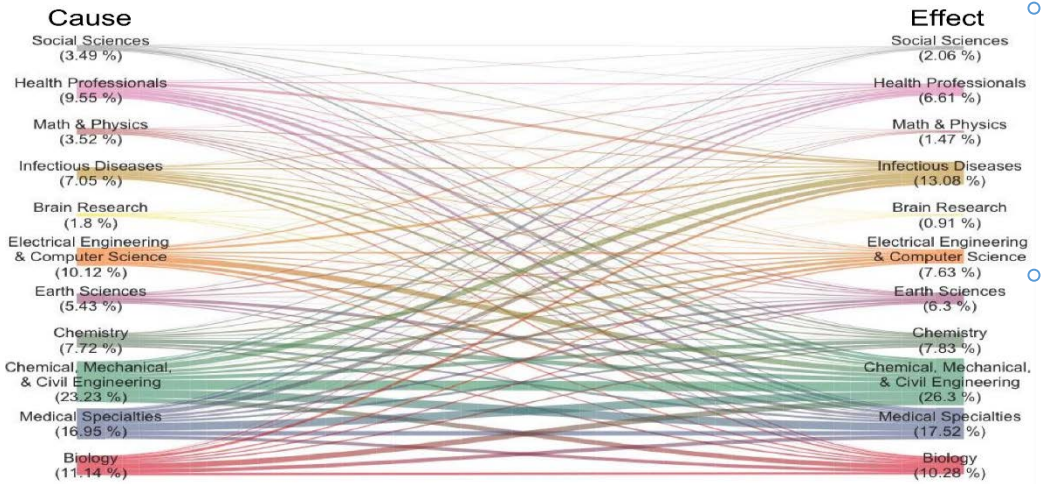
- Thirty-four GRIs' focus areas (among 554 sub-discipline)

DISCIPLINE	SUB-DISCIPLINE	PUBLICATIONS†	DISCIPLINE	SUB-DISCIPLINE	PUBLICATIONS†
BIOTECHNOLOGY (3)	Enzyme Microbiological Techniques	177 (0.64)	CHEMISTRY (10)	Food Chemistry	352 (1.27)
	Microbiology Biotechnology	294.12 (1.06)		Pharmaceutical Design	321.36 (1.16)
	Systematics & Evolutionary Microbiology	321 (1.16)		Phytochemistry	388 (1.4)
MEDICAL SPECIALTIES (2)	Clinical Cancer Research	503.14 (1.81)		Nanotechnology	969.28 (3.49)
	Radiation Protection	272.28 (0.98)		Catalysis	515 (1.85)
CHEMICAL, MECHANICAL, & CIVIL ENGINEERING (8)	Material Science	845.12 (3.04)		EthnoPharmacology	395 (1.42)
	Nuclear Engineering	679 (2.45)		Applied Catalysis	233 (0.84)
	Ceramics	644 (2.32)		Chemistry & Material Science	566.28 (2.04)
	Alloys	289 (1.04)		Liquid Crystals	324 (1.17)
	Filtration Membrane	183 (0.66)		Carbon	586 (2.11)
	Electrochemistry	813 (2.93)	MATH & PHYSICS (7)	Surface Science	1502.86 (5.41)
	Materials Processing	308 (1.11)		Semiconducting Materials	1038 (3.74)
	Sensors & Actuators	243 (0.88)		Astronomy & Astrophysics	397.28 (1.43)
ELECTRICAL ENGINEERING & COMPUTER SCIENCE (3)	Signal Processing	480 (1.73)		High Energy Physics	381.28 (1.37)
	Applied Optics	351.28 (1.27)		Plasma Physics	353 (1.27)
	Solid State Electronics	305 (1.1)		Surface Coating Technology	292 (1.05)
HEALTH PROFESS. (1)	Biomaterials	234 (0.84)		Superconductor Science	722 (2.6)

†Values are extracted from the number of documents (%)

Thematic dependencies

- Dependency distribution across disciplines



- Thematic causality using transfer-entropy
  - Possible lead/lag relations
- Aggregating predictive causalities in portfolios at discipline level
- Biased distribution

Thematic Causality in Research Portfolio

- Disciplines Mainly Involved in Thematic Causality

No.	Cause (%)	Effect (%)
1	Chemical, Mechanical & Civil Engineering (23.23)	Chemical, Mechanical & Civil Engineering (26.3)
2	Medical Specialties (17.51)	Medical Specialties (17.67)
3	Infectious Diseases (13.12)	Biology (10.52)

- Major Causality Pair of Disciplines

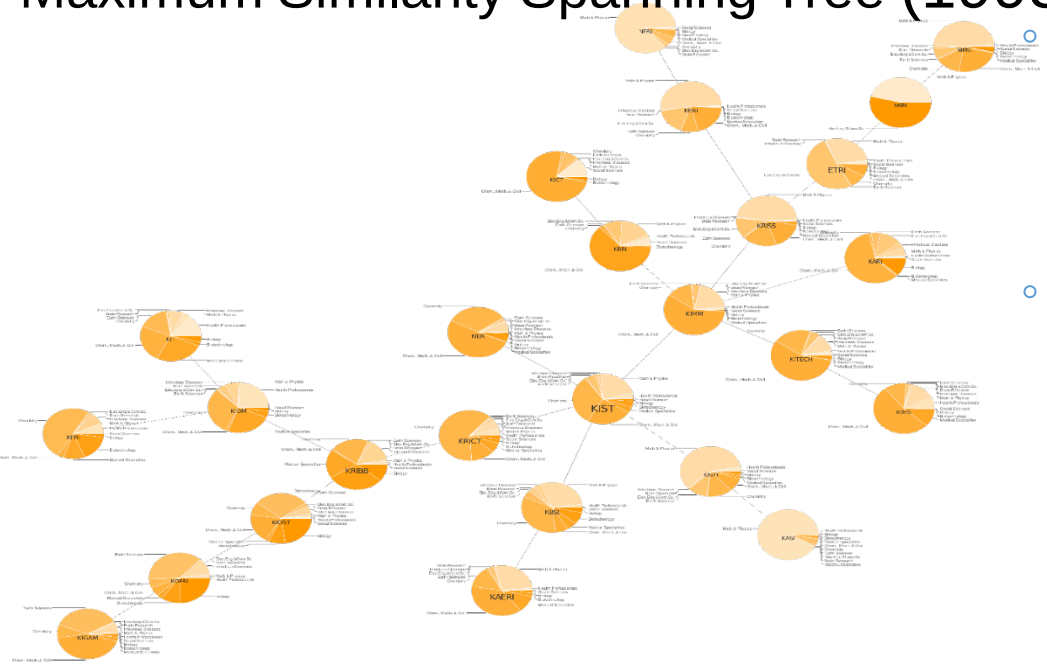
No.	Cause	Effect	% of causality
1	Chemical, Mechanical & Civil Engineering	Chemical, Mechanical & Civil Engineering	5.39
2	Chemical, Mechanical & Civil Engineering	Medical Specialties	4.58
3	Medical Specialties	Chemical, Mechanical & Civil Engineering	4.55

- Thematic Causality of Productive Disciplines

No.	Prolific Discipline (%)	Cause (%)	Effect (%)
1	Chemistry (23.37)	7.75	8.29
2	Chemical, Mechanical & Civil Engineering (22.2)	23.23	26.3
3	Math & Physics (21.11)	1.72	3.13

Thematic Similarity Network

- Maximum Similarity Spanning Tree (1995-2012)



- Node
  - Institutional research portfolios
- Link
  - Relations btwn most

Properties	Values
Nodes	26
Degree	25
Diameter	10
Max. Degree	5 (KIST, KIMM)
Assortativity (Major Discipline)	0.58

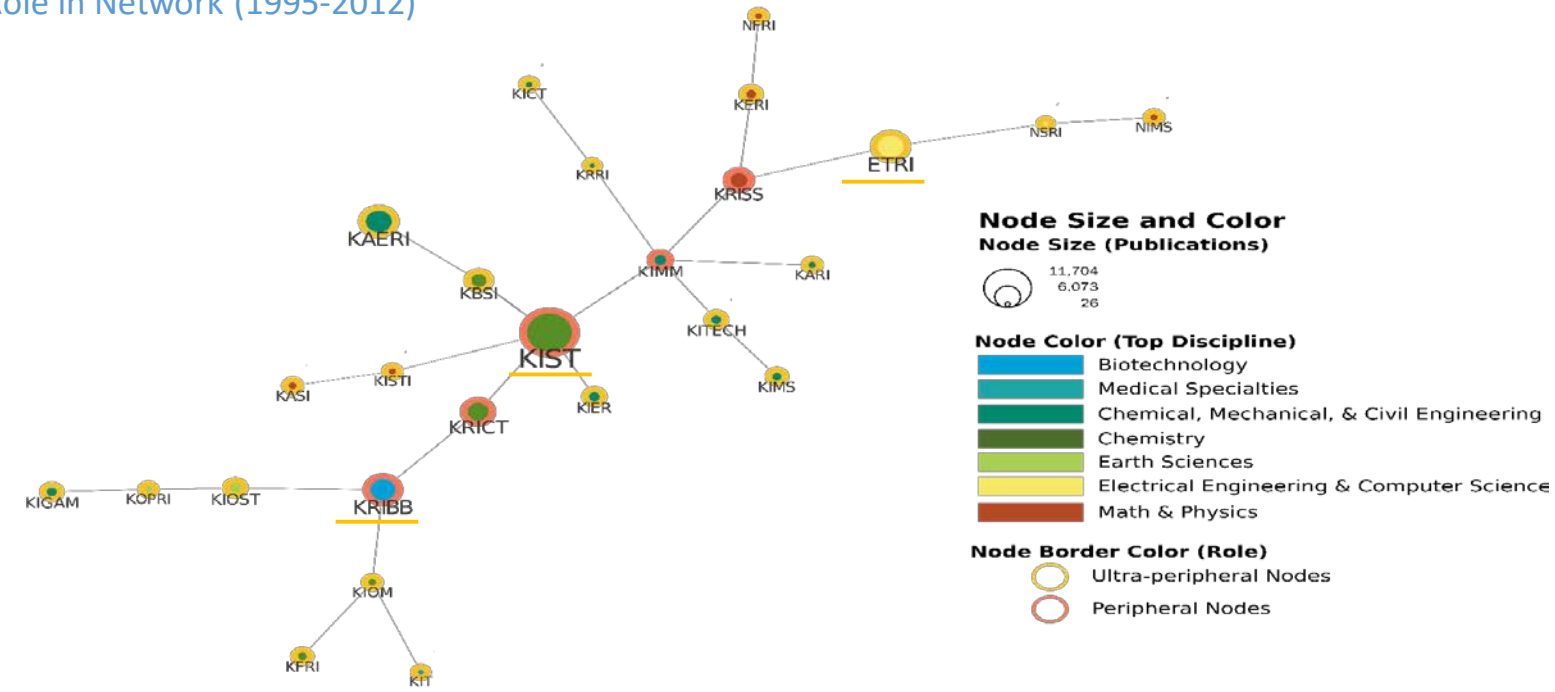
Network Structure

Properties	1995-1997	1998-2000	2001-2003	2004-2006	2007-2009	2010-2012
No. of institutes (nodes)	19	20	24	25	25	25
Maximum degree	7 (KRISS)	6 (KRISS)	4 (KRIBB)	5 (KIST)	5 (KIST)	7(KIMM)
Network diameter	8	9	9	11	10	8
Degree centralization	0.284	0.216	0.091	0.128	0.128	0.212
Betweenness centralization	0.623	0.598	0.602	0.561	0.543	0.63
Closeness centralization	0.287	0.297	0.271	0.215	0.23	0.315

- Overlapping Temporal Structure in Inter-portfolio Networks
  - Average degree: 2.84
  - Constant interactions over time (more than five times):
    7.04% share of all links
    KRIBB—KFRI, KRIBB—KIOM, KITECH–KIMM, KRICT—KIST, KRISS—KBSI

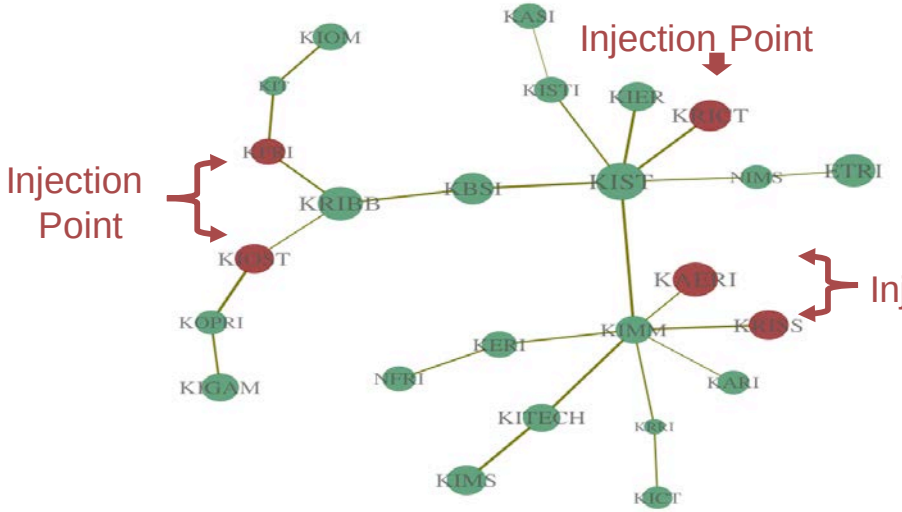
Network Structure

Role in Network (1995-2012)



Key Organizations

- To influence throughout network

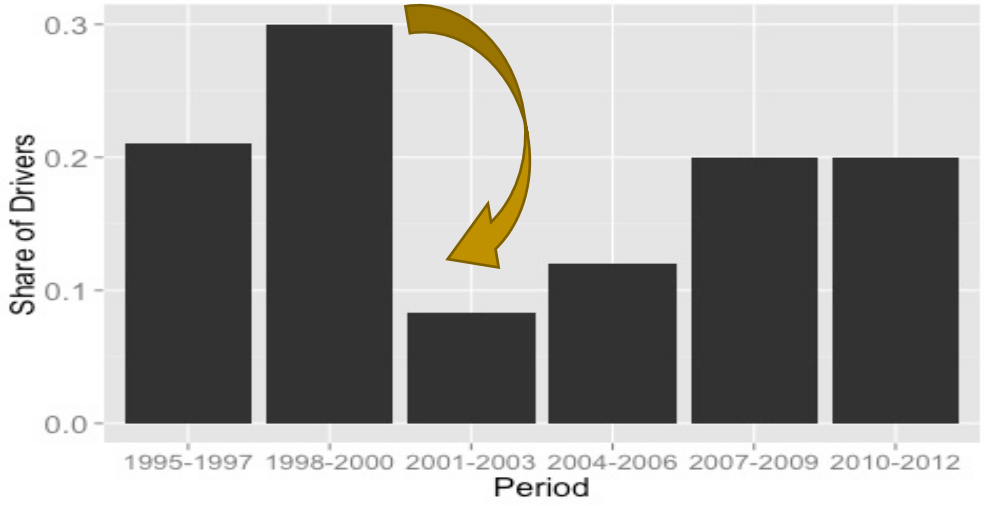


e.g., Research Similarity Network, 2010-2012

- Extracted by structural controllability
  - Theoretical results
  - Based on network structure
  - Minimum number of injection points
- Injection points = initiators of changes

Key Organizations

- Share of injection points over time



- Greater number of injection points
  - Increasing management burden
- Structural efficiency of inter-organizational network
- Governance changes in 1998-2003
  - Rearrangement to remove redundancy
  - Operating under research councils in 1999

Summary

Research structure of Korean GRIs

- Complex systems perspective
- Diagnosis thematic balance
- Estimate injection points of energy to steer sub-organizational network

Questions & Answers

1. How has GRIs' research been evolved?
   - Foundation discipline: Chemistry
   - Developing discipline: Chemical, Mechanical & Civil Engineering
   - Emerging discipline: Medical Specialties, Biology, Infectious Diseases

2. Which GRI takes principal place in functioning networks?
   - Comprehensive portfolio: KRISS ('90s), KIST ('00s, overall)
   - Inter-community connector: KIST, KRISS, KRIBB, KRICT, KIMM

3. How much does GRIs' portfolio meet needs for balance in research areas?
   - Biased development toward a few discipline.
     e.g., Chemical, Mechanical & Civil Engineering
   - Necessity to accelerate expansion with superiority in new area
   - Concern for in-depth research because of unstable portfolio structure

Method

Study Population

- 3 public research institutions in different countries
  - 26 Korean Government-funded research institutes (GRIs)
  - 61 units in Max Planck Gesellschaft (MPG) in Germany
  - 17 National Laboratories (NLs) in the United States (US)

Data Collection

Bibliographic data of sub-organizations

- Source: Thomson Reuters Web of Knowledge
- 18 years are divided into 6 periods (1995-2012, 1 period = 3 yrs)
- Over 337,000 articles: GRIs: 59,333, MPG: 85,540, NLs: 192,544

Portfolio Identification

Journal title based classification system

- UCSD map of science
- 554 sub-disciplines within 13 disciplines

Analysis

Possible causality between sub-disciplines in a portfolio

- Information-theoretic indicator, transfer-entropy
- Distributions across disciplines

Causality network

- Aggregation of thematic dependencies in sub-organizational portfolios
- Structural properties: degree distribution
- Sub-disciplinary scores: PageRank algorithm

Determining Significant Node

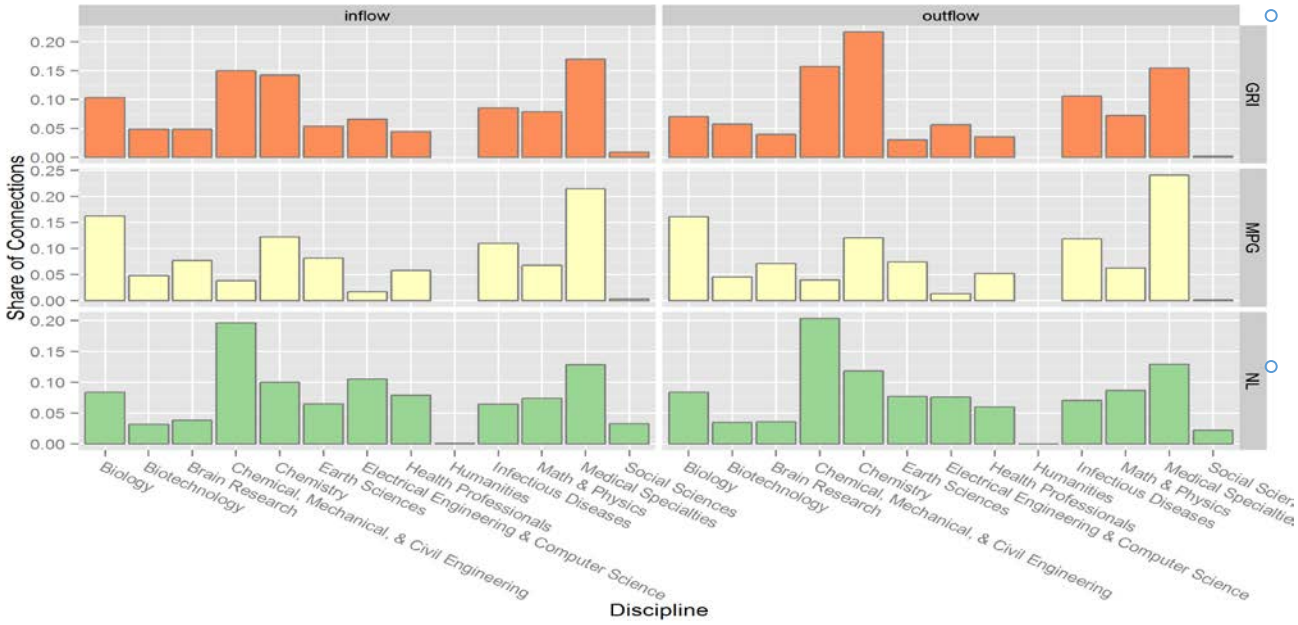
- PageRank algorithm (Brin and Page 1998)
  - Normalize importance of nodes based on link structure
  - Score webpages on Google's search engine

- Weighted PageRank algorithm () (Ding 2011)
  - Determine nodal degree of being influenced by others
  - Consider number of inbounds and frequencies of appearances

    - set of nodes that point node
    - : sum of weights on outbound links of node
    - : weight assigned to node
    - : damping factor, 0.85

Thematic Dependency

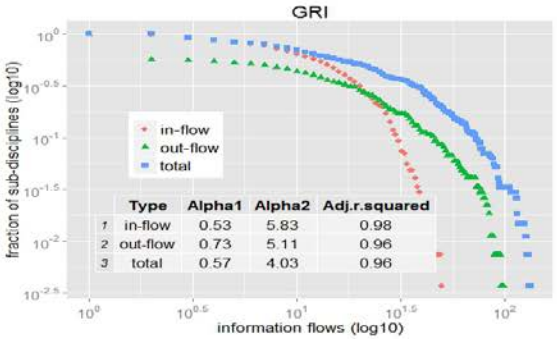
- Institutional distribution across disciplines



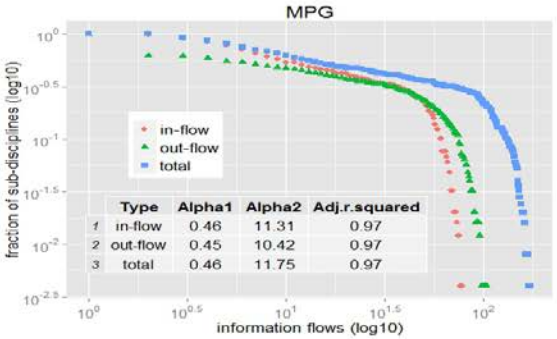
- Aggregating predictive causalities in portfolios at discipline level
  - Inflow = effect
  - Outflow = cause
- Biased distribution
  - GRI: Medical Specialties, Chemistry
  - MPG: Medical Specialties
  - NL: Chemical, Mechanical, and Civil Eng.

Dependency Network

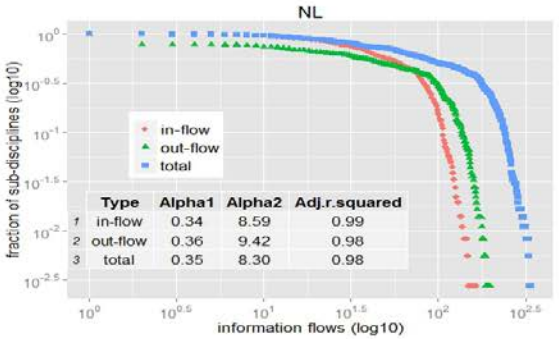
- Degree distribution of organizational thematic network



	Type	Alpha1	Alpha2	Adj.r.squared
1	in-flow	0.53	5.83	0.98
2	out-flow	0.73	5.11	0.96
3	total	0.57	4.03	0.96



	Type	Alpha1	Alpha2	Adj.r.squared
1	in-flow	0.46	11.31	0.97
2	out-flow	0.45	10.42	0.97
3	total	0.46	11.75	0.97

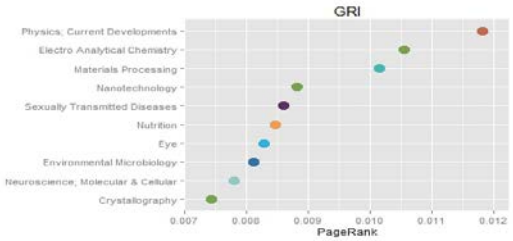


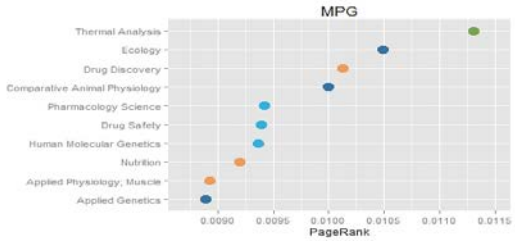
	Type	Alpha1	Alpha2	Adj.r.squared
1	in-flow	0.34	8.59	0.99
2	out-flow	0.36	9.42	0.98
3	total	0.35	8.30	0.98

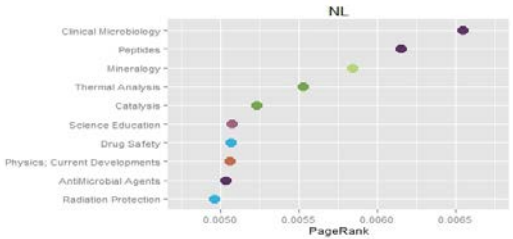
- Concentrated sub-disciplines of causality
- Dichotomous structure
  - Head (Alpha 1) and Tail (Alpha 2)

Dependency Network

- Top-10 sub-disciplines by being influenced by others







- Nodal score using PageRank algorithm
- Colored by discipline
- Top disciplines most frequently appeared
  - GRIs: chemistry
  - NLs: infectious disease
  - MPG: biology, brain research, and health professionals
- Most subordinates are affected
  - 44.4% GRIs
  - 80.3% MPG
  - 57.6% NLs

Summary

- Extraction of thematic dependencies
  - Developmental dynamics of disciplines
  - Different concentrated areas by different organizations

Contributions

- Track developmental trajectories of research organizations
- Provide quantitative information for research management

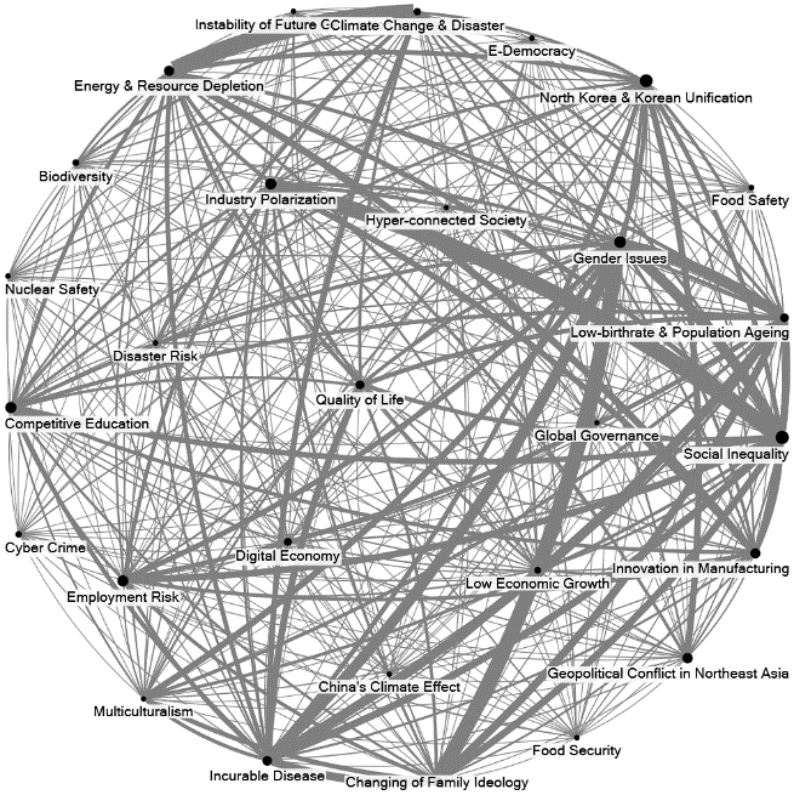
Networks of national interests

Hyunuk Kim, Taekho You, Sang-Jin Ahn, and Woo-Sung Jung, “Embracing networks of national policy research in future foresight”, *International Journal of Knowledge-Based Development*, 7(2), pp.107-124, 2016.

- Based on policy papers from national research institutes, we constructed networks of national interests for fifteen years
  - Data source: National Knowledge Information System (NKIS, www.nkis.re.kr)
  - Twenty-eight social issues such as social inequality, multiculturalism, energy & resource depletion, and so on (During 2000-2014)
    - These issues are listed in the survey conducted by Future Preparatory Committee of Korea in 2015
- Split the dataset for every five years

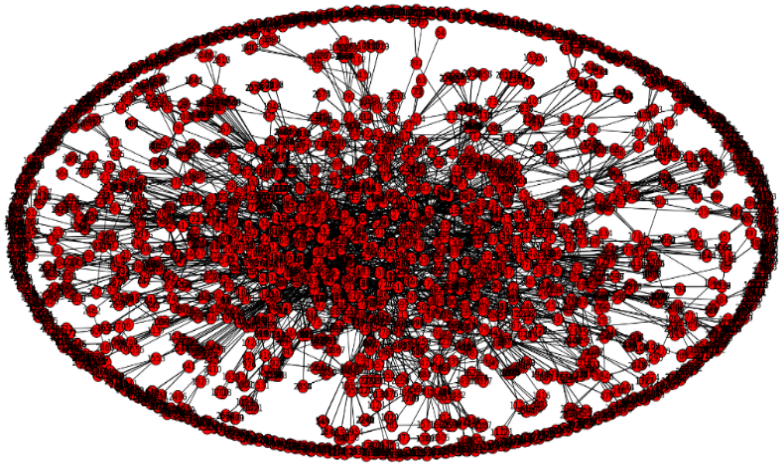
2000~2004	2005~2009	2010~2014	Total
5,093	7,155	10,235	22,483

Issue Network



2010-2014, NodeXL

Keyword Network



Energy & Resource Depletion(2010-2014, NetworkX)

Centrality analysis

- PageRank algorithm
  : to measure the influence of nodes in the network, proposed by Larry Page and Sergey Brin, co-founders of Google Inc.
  - Initial stage: every node has a PageRank value of 1/n, the value is divided by the number of neighbors and is transferred to its neighbors
  - Next stage: PageRank value is updated to the sum of values it received
- Betweenness centrality:
  - : the number of shortest paths from node to
  - : the number of shortest paths from node to that pass through node

PageRank

Rank	2000~2004	2005~2009	2010~2014
1	Social Inequality	Social Inequality	Social Inequality
2	North Korea & Korean Unification	Gender Issues	Gender Issues
3	Gender Issues	Competitive Education	Incurable Disease
4	Industry Polarization	Industry Polarization	Energy & Resource Depletion
5	Competitive Education	Incurable Disease	Low-birthrate & Population Ageing
6	Employment Risk	Changing of Family Ideology	Changing of Family Ideology
7	Geopolitical Conflict in Northeast Asia	Low-birthrate & Population Ageing	Climate Change & Disaster
8	Energy & Resource Depletion	North Korea & Korean Unification	Industry Polarization
9	Innovation in Manufacturing	Energy & Resource Depletion	North Korea & Korean Unification
10	Changing of Family Ideology	Employment Risk	Innovation in Manufacturing
11	Incurable Disease	Innovation in Manufacturing	Competitive Education
12	Quality of Life	Quality of Life	Quality of Life
13	Low-birthrate & Population Ageing	Climate Change & Disaster	Employment Risk
14	Digital Economy	Geopolitical Conflict in Northeast Asia	Multiculturalism
15	Climate Change & Disaster	Digital Economy	Geopolitical Conflict in Northeast Asia
16	Low Economic Growth	Multiculturalism	Low Economic Growth
17	Biodiversity	Low Economic Growth	Digital Economy
18	Cyber Crime	Disaster Risk	Disaster Risk
19	E-Democracy	Global Governance	Biodiversity
20	Food Safety	E-Democracy	Global Governance

Betweenness centrality

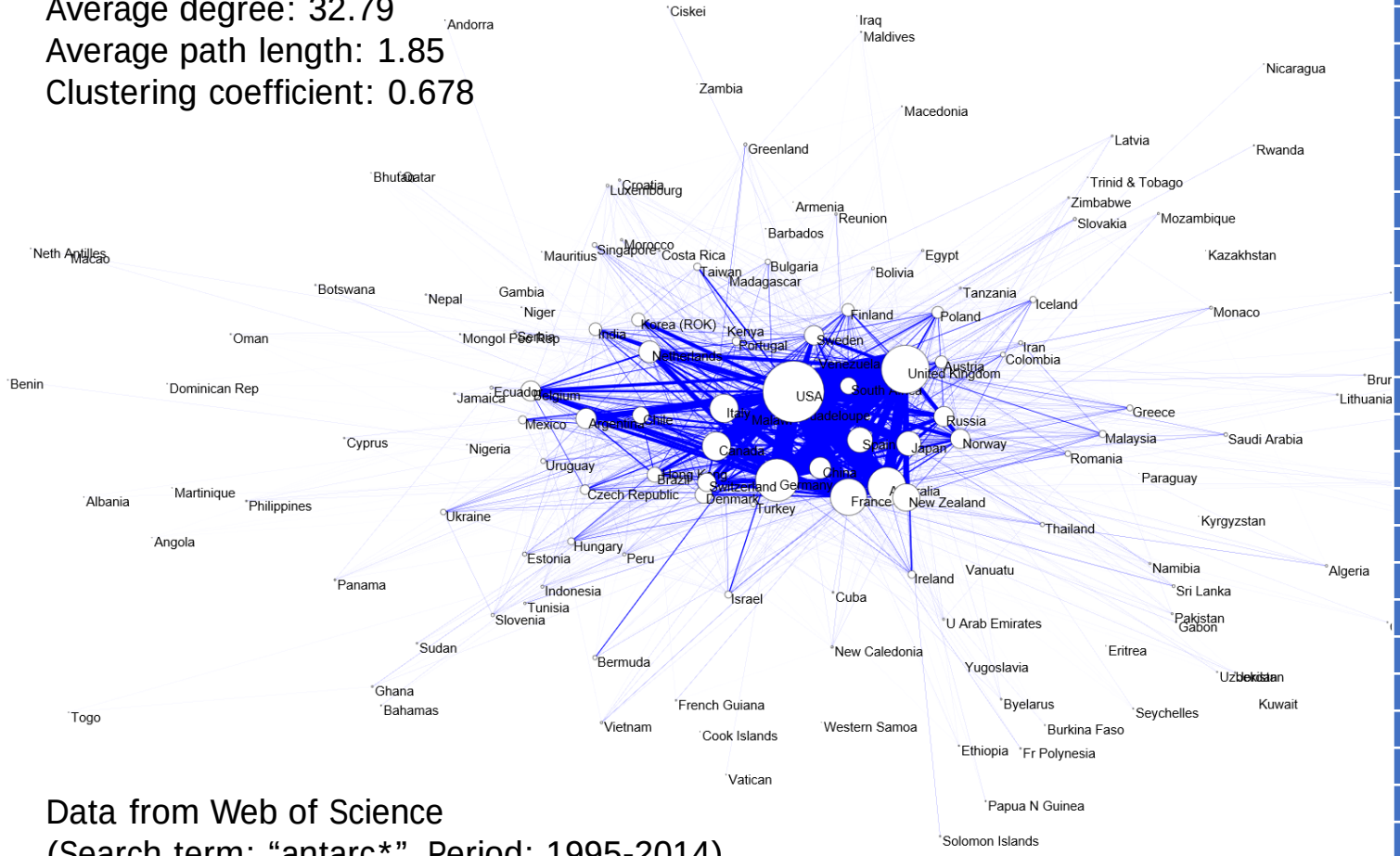
Low-birthrate & Population Ageing			
Rank	2000~2004	2005~2009	2010~2014
1	Finance	Low-birthrate	Low-birthrate
2	Ageing	Labor market	Ageing
3	Ageing society	Ageing	Policy
4	Impact	Family	Fund
5	Response	Baby sitter	2012
6	National pension fund	Social welfare	Fertility
7	Childcare	Social integration	Population policy
8	Labor market	Economic growth	Research
9	Current state	Economy	Agenda
10	Perspective	Female	Rural

Changing of Family Ideology			
Rank	2000~2004	2005~2009	2010~2014
1	Change	Low-birthrate	Low-birthrate
2	North & South Korea	Female	Ageing
3	Economic activity	Ageing	Female
4	Behavior	Child care	Multi-cultural family
5	North Korea	Multi-culture	Socially disadvantaged class
6	Family	Japan	Economic crisis
7	Female	USA	Policy
8	Labor market	Sweden	Korea
9	Women's policy	Labor	Teenager
10	Compensation	Family	Behavior

Collaboration structure in Antarctic science

Hyunuk Kim and Woo-Sung Jung, “Bibliometric analysis of collaboration network and the role of research station in Antarctic science”, *Industrial Engineering & Management Systems*, 15(1), pp.92-98, 2016.

Size: 151
Average degree: 32.79
Average path length: 1.85
Clustering coefficient: 0.678



Data from Web of Science
(Search term: “antarc*”, Period: 1995-2014)

Rank	Country
1	USA
2	United Kingdom
3	Germany
4	Australia
5	France
6	Canada
7	Italy
8	New Zealand
9	Spain
10	Japan
11	Netherlands
12	China
13	Argentina
14	Belgium
15	Russia
16	Norway
17	Sweden
18	Switzerland
19	Denmark
20	South Africa
21	Chile
22	Brazil
23	Korea (ROK)
24	India
25	Finland

- Implement modularity maximization algorithm suggested by Aaron Clauset, Mark EJ Newman, and Cristopher Moore (PRE, 2004) to detect communities in the collaboration network
- Modularity:

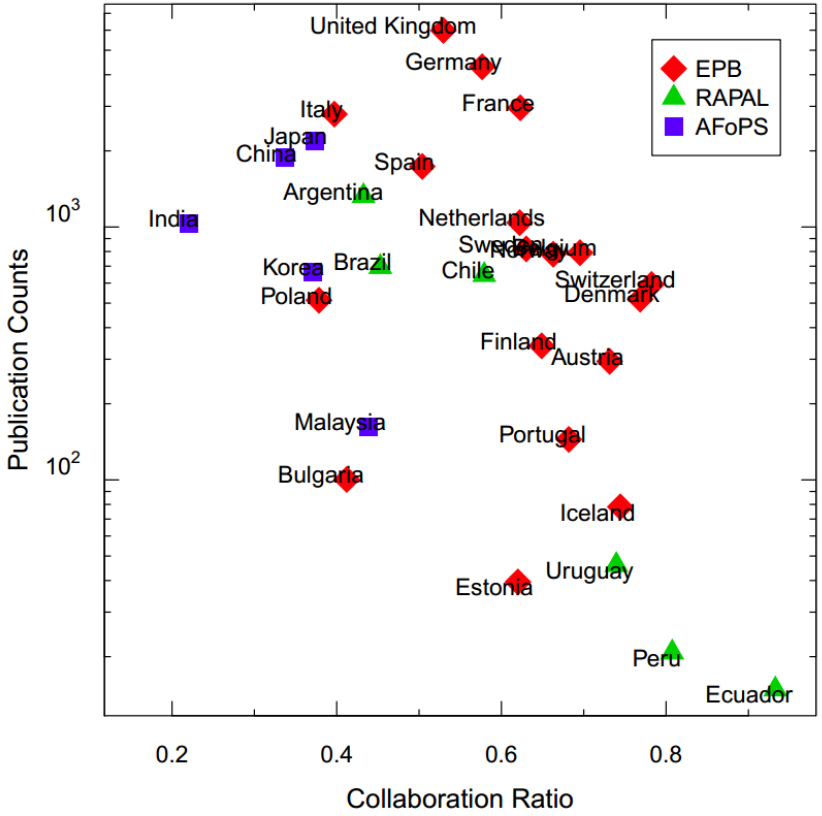
- 24 communities with a mean size of about 6 countries, =0.587

Size	Countries
26	Algeria, Belgium, Botswana, Bulgaria, Burkina Faso, Chad, Cook Islands, Czech Republic, Ethiopia, Fr Polynesia, France, French Guiana, Gabon, Israel, Kenya, Luxembourg, Macedonia, Madagascar, Monaco, Morocco, New Caledonia, Niger, Reunion, Slovakia, Tunisia, Western Samoa
21	Angola, Brazil, Chile, Colombia, Costa Rica, Cuba, Ecuador, Gambia, Guadeloupe, Lithuania, Martinique, Mexico, Nicaragua, Panama, Paraguay, Peru, Portugal, Spain, Togo, Uruguay, Venezuela
14	Bolivia, Denmark, Dominican Rep, Estonia, Finland, Greenland, Hungary, Iceland, Kyrgyzstan, Mozambique, Norway, Romania, Sweden, U Arab Emirates
13	Brunei, Ciskei, Cyprus, Eritrea, Malawi, Namibia, Nigeria, Rep of Georgia, South Africa, Sudan, Tanzania, Zambia, Zimbabwe
11	Austria, Barbados, Benin, Germany, Jamaica, Jordan, Neth Antilles, Netherlands, Sri Lanka, Switzerland, Tajikistan
9	Bahamas, Bahrain, Bermuda, Ghana, Malagasy Republ, Rwanda, USA, Uzbekistan, Vatican
8	Bangladesh, Cameroon, Indonesia, Japan, Philippines, Singapore, Thailand, Vietnam
7	Byelarus, Croatia, Iraq, Poland, Slovenia, Turkey, Ukraine
6	Australia, Fiji, Mauritius, New Zealand, Papua N Guinea, Solomon Islands

Regional proximity seems to be important in Antarctic science collaboration network.

Regional research communities

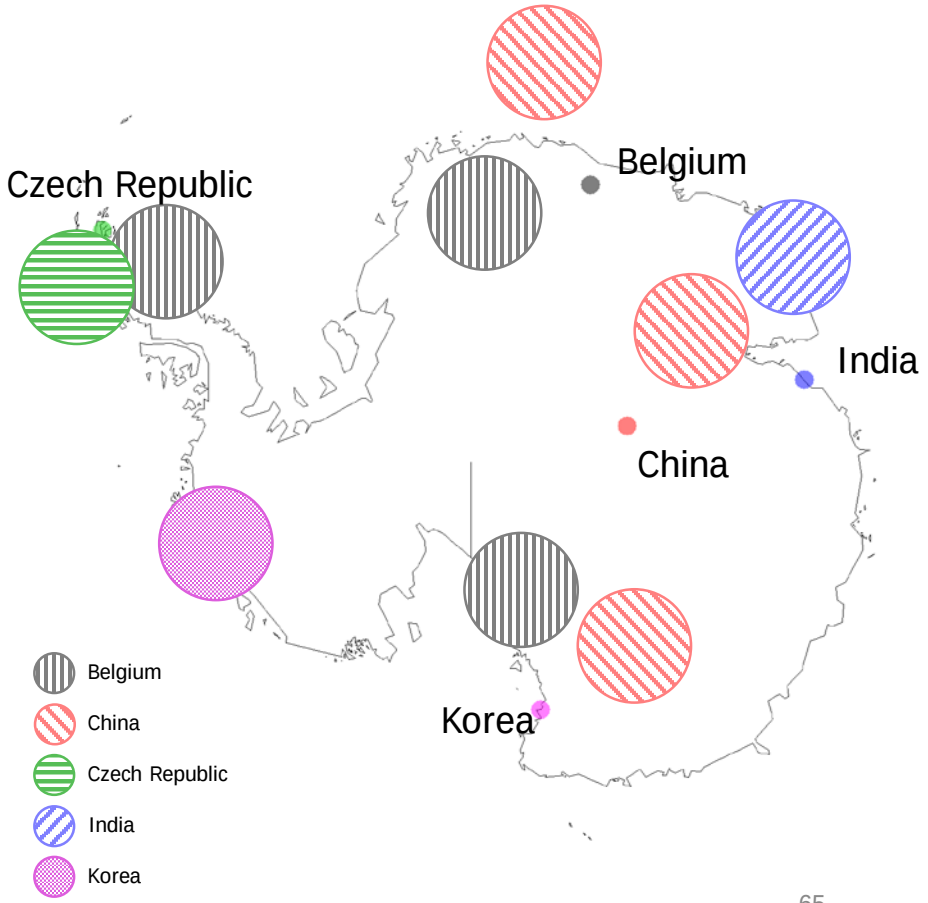
- Publication counts:
  total number of papers that a country involves
- Collaboration ratio:
  number of collaboration papers / publication counts
- Asian Forum for Polar Sciences (AFoPS)
  : China, India, Japan, Malaysia, and Korea
- European Polar Board (EPB)
  : Austria, Belgium, Bulgaria, Denmark, Estonia, Finland, France, Germany, Iceland, Italy, Netherlands, Norway, Poland, Portugal, Spain, Sweden, Switzerland, and United Kingdom
- *Reunión de Administradores de Programas Antárticos Latinoamericanos* (RAPAL)
  : Argentina, Brazil, Chile, Uruguay, Ecuador, and Peru



Emerging geographical keywords

- Detect sudden increase of research keywords around installation time for Belgium, China, Czech Republic, India, and Korea

Country	Keyword	Counts
Belgium	South Shetland Islands	36
	McMurdo Dry Valleys	15
	Deception Island	14
	James Ross Island	13
	Dronning Maud Land	11
	Western Weddell Sea	10
China	Southern Ocean	71
	Prince Charles Mountains	15
	Victoria Land	11
Czech Republic	James Ross Island	23
	South Shetland Islands	20
	East Antarctica	15
India	Larsemann Hills	11
Korea	Amundsen Sea	6
	Pine Island Glacier	5



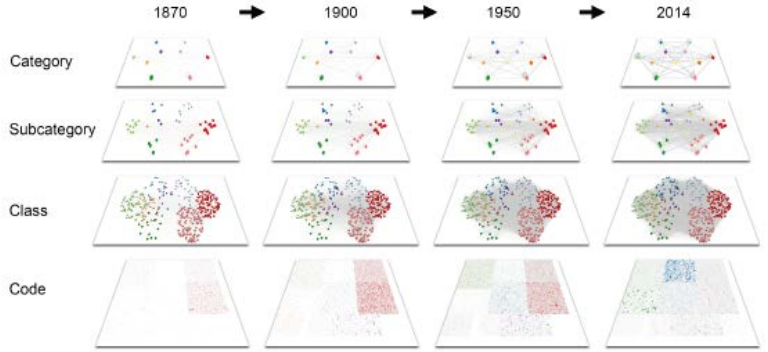
Quantifying multilevel evolution of technology combination

(In preparation)

With Daniel Kim (KAIST), Young-Ho Eom (Universidad Carlos III de Madrid), Hawoong Jeong (KAIST), Hyejin Youn (University of Oxford)

- Patents, which claim inventor's rights on technological novelty, have been used in observing technology trends, forecasting future technology, and planning R&D policies [1]
- Combination process of technologies plays an crucial role in technology innovation [2]

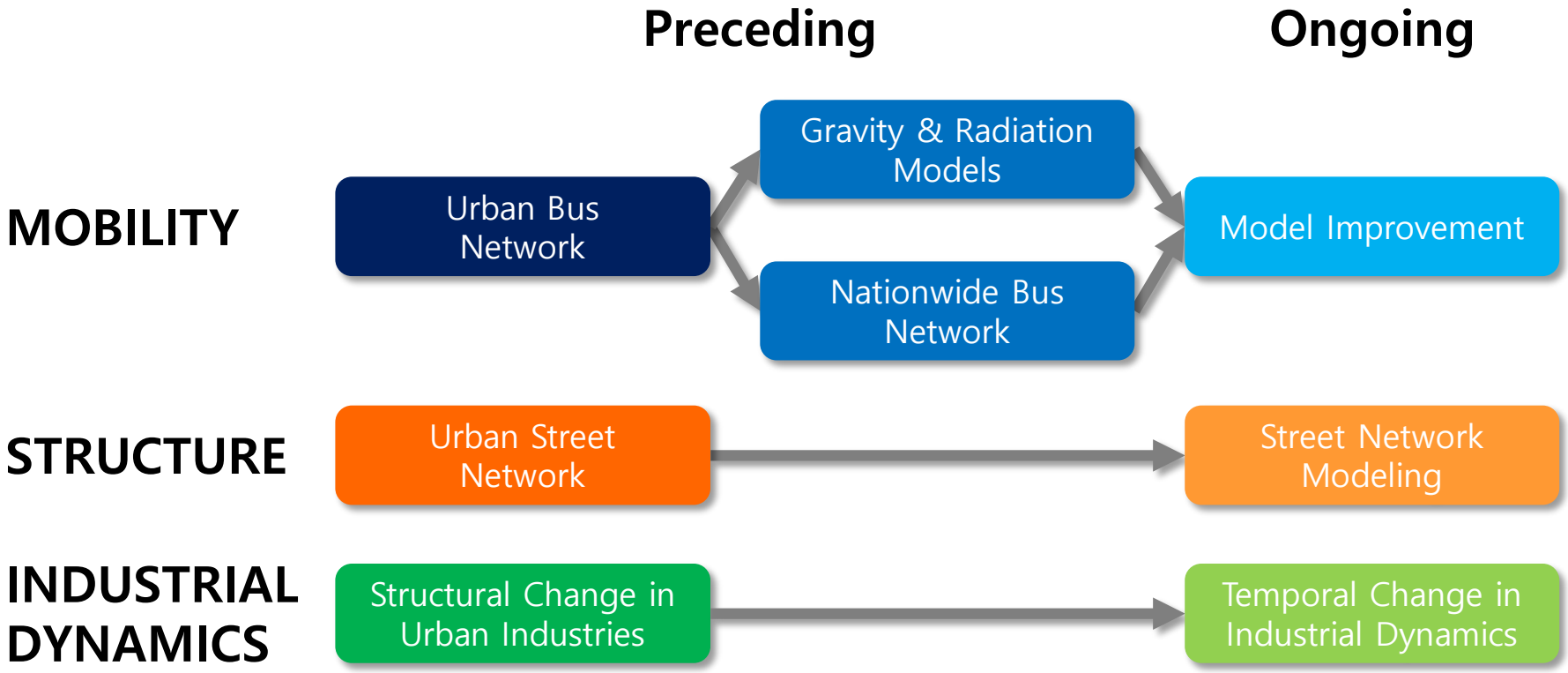
1. Extracting trends and backbone of technology code combination
2. Modeling patent citation patterns



[1] Abbas, A., Zhang, L., & Khan, S. U. (2014). A literature review on the state-of-the-art in patent analysis. *World Patent Information*, *37*, 3-13.
[2] Wagner, A., & Rosen, W. (2014). Spaces of the possible: universal Darwinism and the wall between technological and biological innovation. *Journal of The Royal Society Interface*, *11*(97), 20131190.

Transportation

Spatially Embedded System

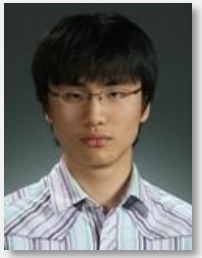


Project Members

Complexity in Social System Lab.

Woo-Sung Jung

Inho Hong



Byoung-Hwa Lee

Hang-Hyun Jo

Collaboration

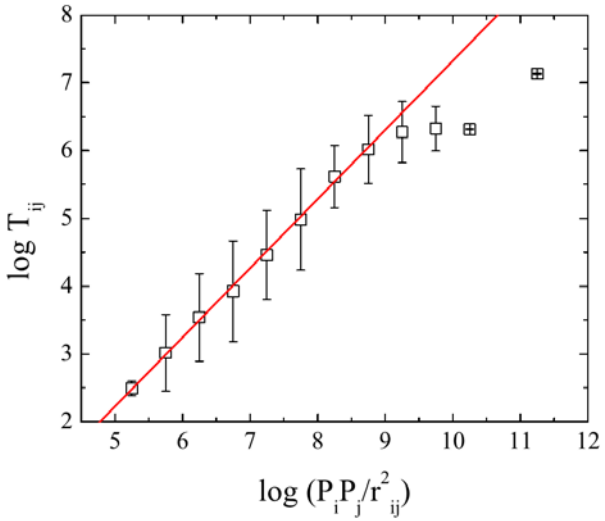
+

U. of Oxford

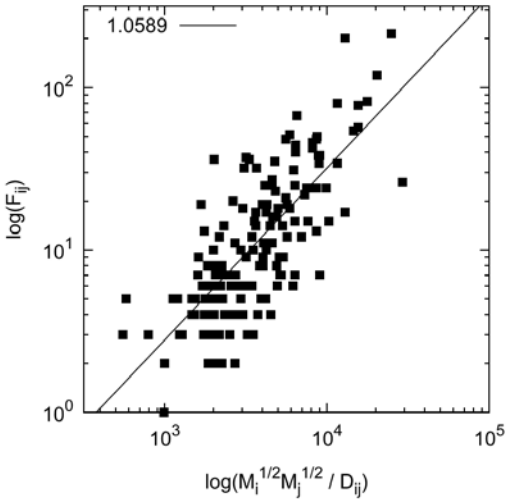
Hyejin Youn

1. Mobility Models

Korean Highway[1]



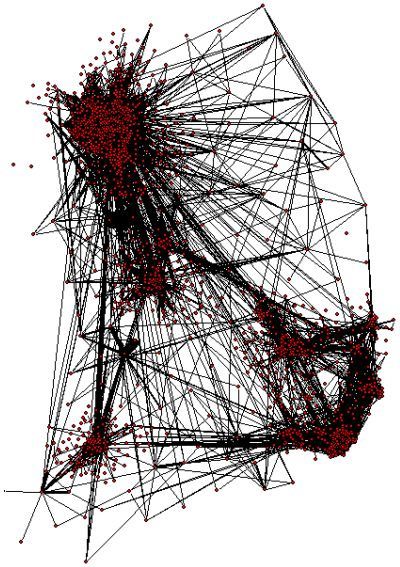
Korean Intercity Buses[2]

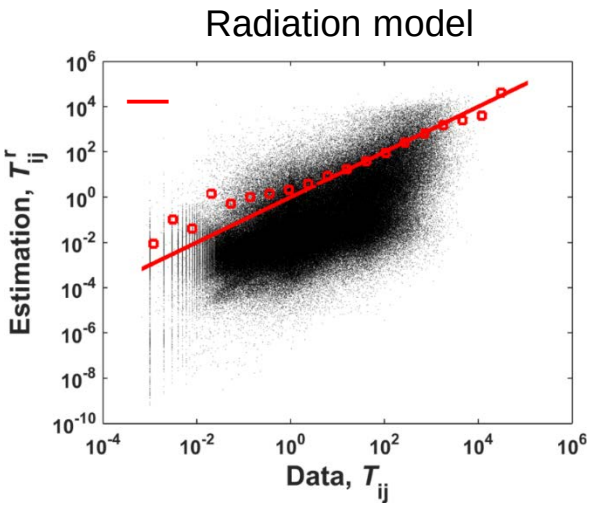


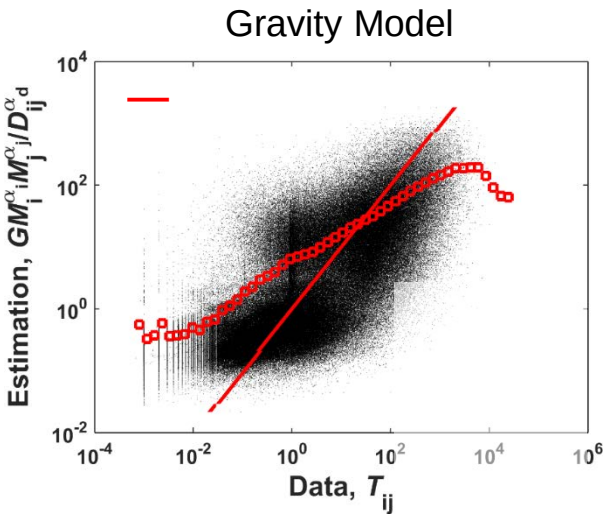
- Gravity model explained the mobility patterns in Korea.

[1]W.-S. Jung *et al.*, *Eur. Phys. Lett.* **81**, 48005 (2008)
[2]O. Kwon and W.-S. Jung, *Physica A* **391**, 4261 (2012)

1. Mobility Models (Ongoing)

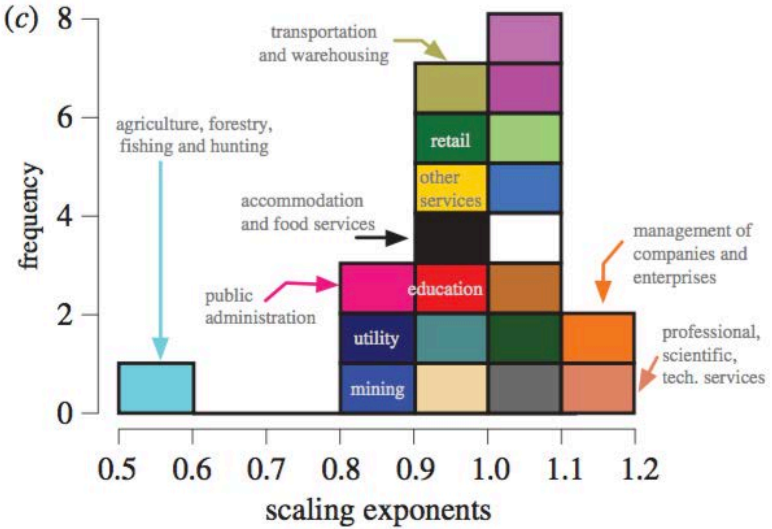


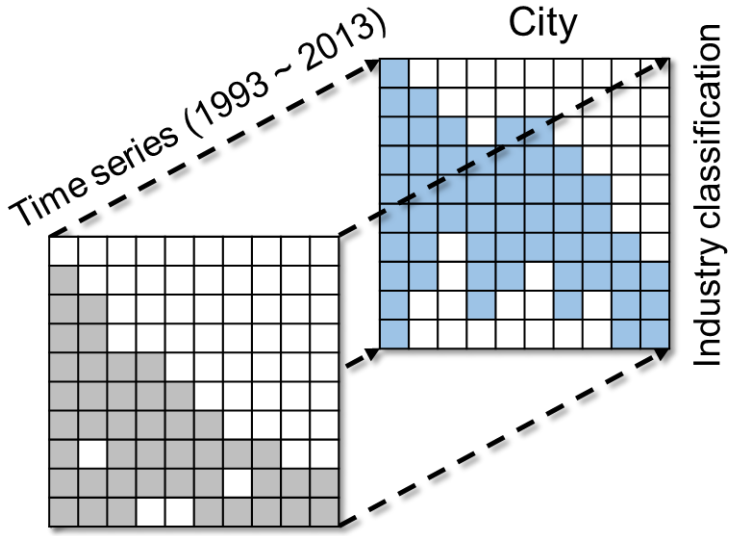




- Successful estimation by radiation and gravity models for the bus system
- Better fitting on the averaged estimations by radiation model

2. Industrial Dynamics – Introduction



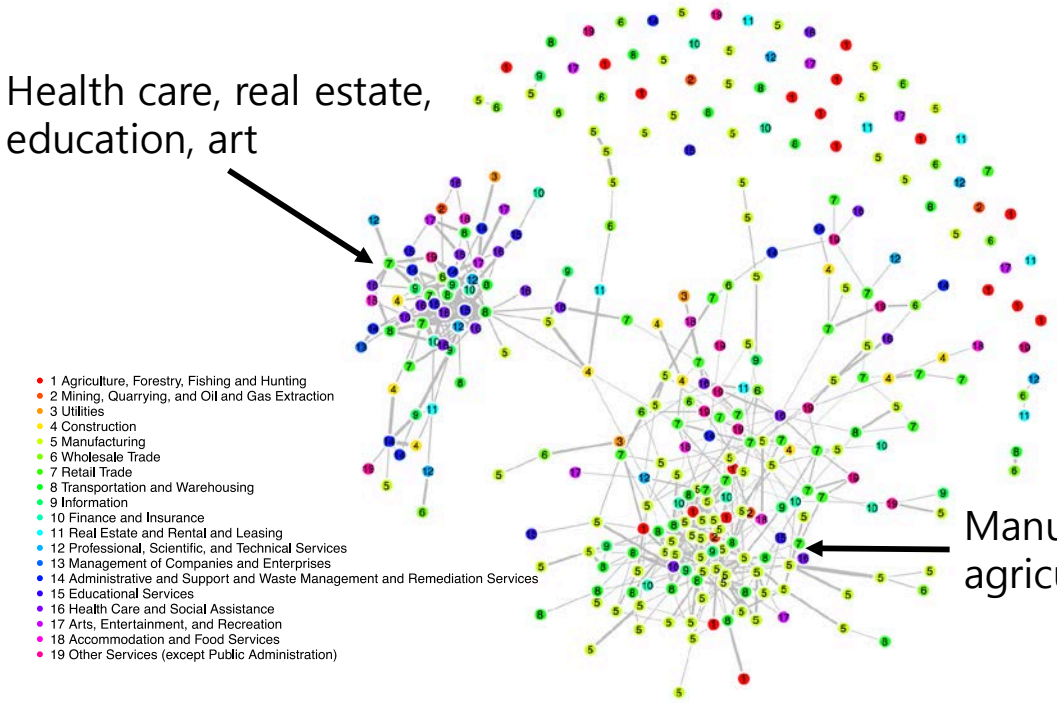


H. Youn, *et al. J. R. Soc. Interface* **13,** 20150937 (2016).

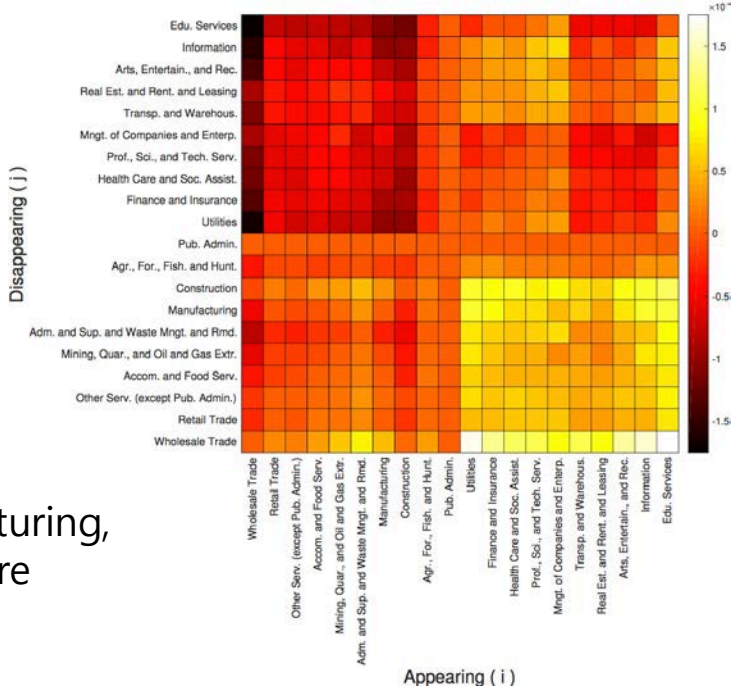
- Comparative advantage of urban industries: industrial trajectory by city size
- Temporal analysis on the transition patterns by time series data

2. Industrial Dynamics – Result

Health care, real estate, education, art



Manufacturing, agriculture



- Multiscale backbone analysis[1] on the correlations of appearing industries
- Two clusters & industrial transition: from primary & secondary to tertiary sectors

[1]M. Á. Serrano, M. Boguná, & A. Vespignani, *PNAS* **106,** 6483–6488 (2009).

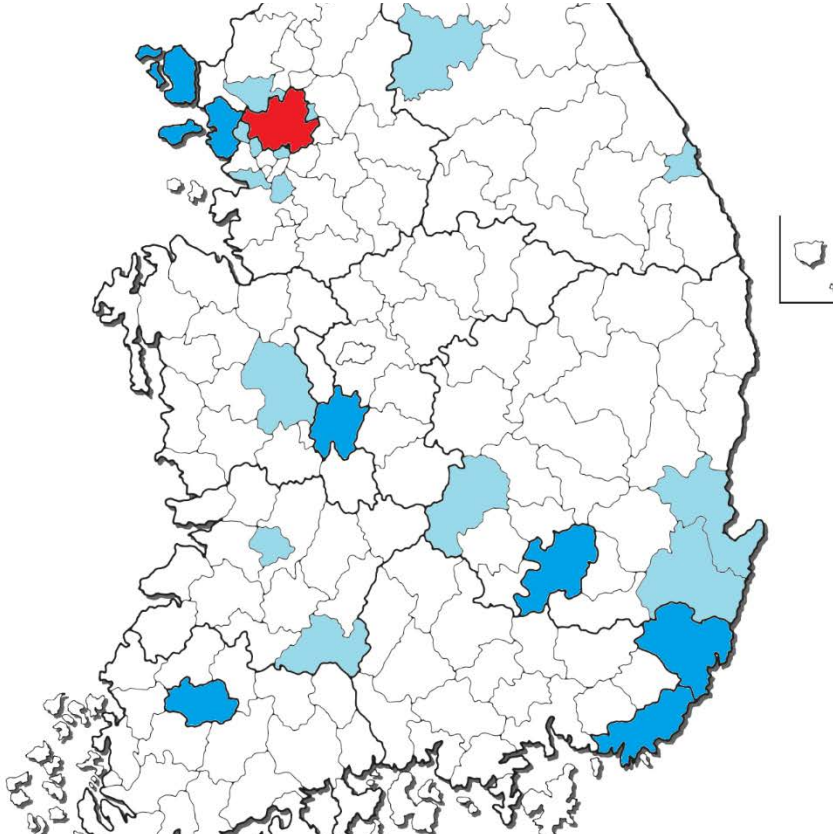
Database: Standard Node-Link

- Ministry of Land, Infrastructure and Transport
  - Intelligent Transportation Systems (ITS)
  - Assign the ID to all the nodes and links in Korea, from local roads to highways

- Standard node-link database
  - /
  - Nodes – Intersections and both ends tunnels or bridges
  - Information
    - Node – Geographic coordinates (GPS)
    - Link – Actual lengths of roads

Analyzed Cities

- Seoul + 6 metropolitan cities + 15 other cities



- Among 15,
  - Capital area: 7
  - Local area: 8
  - Coast: 6
  - Urban-rural integrated: 6
- Diverse role, topography, size, …

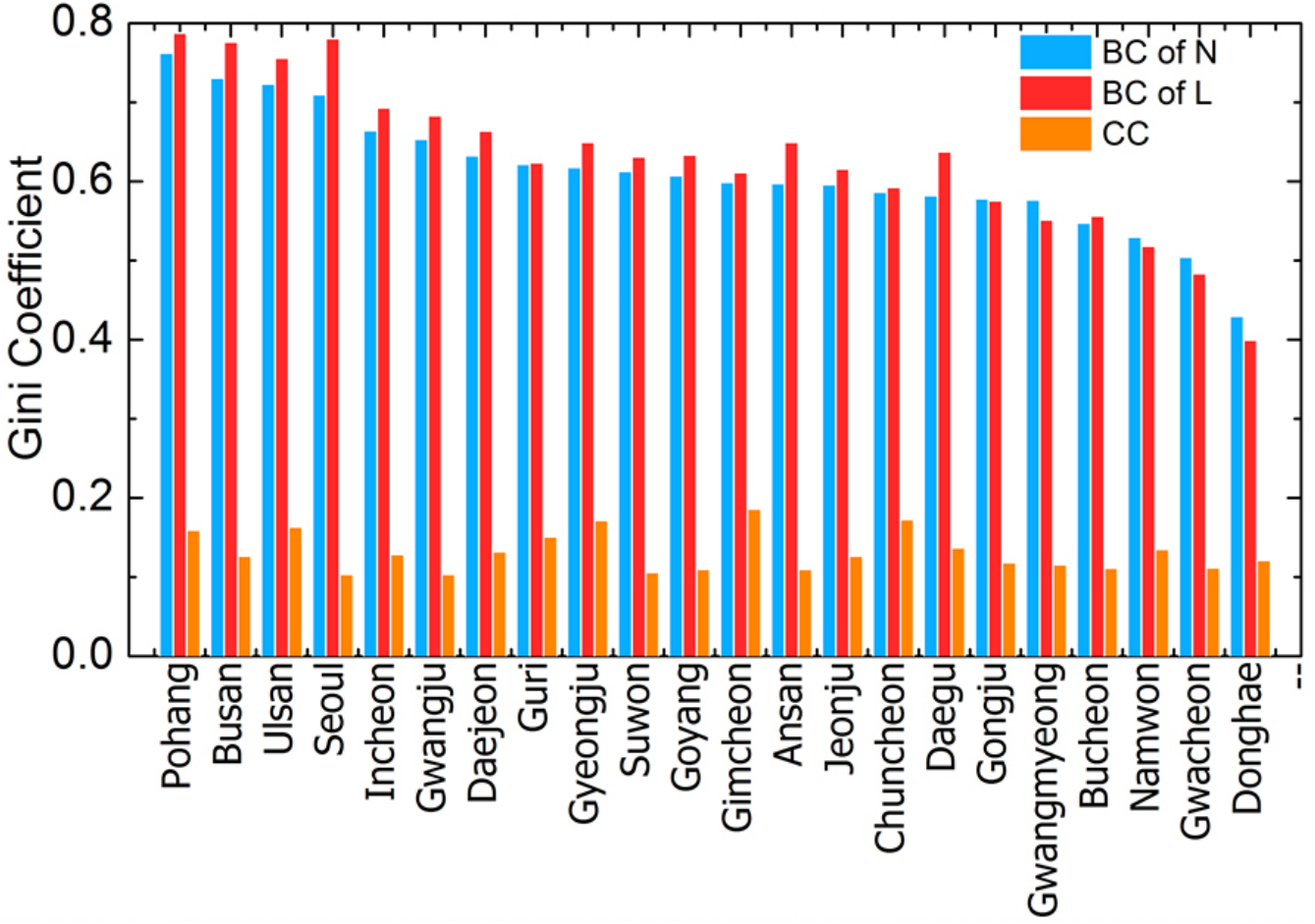
	Population	Area (km^2)
Seoul	10,103,230	605
Busan	3,557,716	766
Incheon	2,985,831	1041
Daegu	2,518,467	884
Daejeon	1,551,931	540
Gwangju	1,492,948	501
Ulsan	1,192,262	1060
Suwon	1,213,665	121
Goyang	1,028,237	267
Bucheon	849,064	54
Ansan	696,934	150
Jeonju	652,858	206
Pohang	519,244	1129
Gwangmyeong	346,888	39
Chuncheon	281,005	1116
Gyeongju	261,535	1324
Guri	186,774	33
Gimcheon	140,085	1010
Gongju	113,294	864
Donghae	94,562	180
Namwon	84,856	753
Gwacheon	69,031	36
Average	1,360,928	576.28

Ex. Betweenness Centrality Map – Seoul

- Size of circle: BC of node / Width of line: BC of link
- High BC – heavy traffic
  - ex. Near the bus terminal in Gangnam, Olympic highway, and central business district (CBD)

Gini Coefficients

- Tendency of big size cities have high Gini of BC
- However, their correlation is not significant
- Pohang is an outlier



Pearson Correlation Coefficient

	Popu-lation	Area	N	L	Total Length	Average Length	BC of N	BC of L	CC
Population		0.10	0.95	0.96	0.93	-0.35	0.47	0.55	-0.33
Area	0.10		0.21	0.18	0.38	0.42	0.46	0.47	0.67
N	**0.95**	0.21		1.00	0.98	-0.38	0.61	0.67	-0.24
L	**0.96**	0.18	**1.00**		0.97	-0.37	0.57	0.64	-0.26
Total Length	**0.93**	0.38	**0.98**	**0.97**		-0.28	0.65	0.72	-0.13
Average Length	**-0.35**	0.42	**-0.38**	**-0.37**	**-0.28**		-0.43	-0.45	0.33
BC of N	0.47	0.46	**0.61**	0.57	**0.65**	**-0.43**		0.98	0.21
BC of L	0.55	0.47	**0.67**	**0.64**	**0.72**	**-0.45**	**0.98**		0.16
CC	**-0.33**	**0.67**	**-0.24**	**-0.26**	**-0.13**	0.33	0.21	0.16	

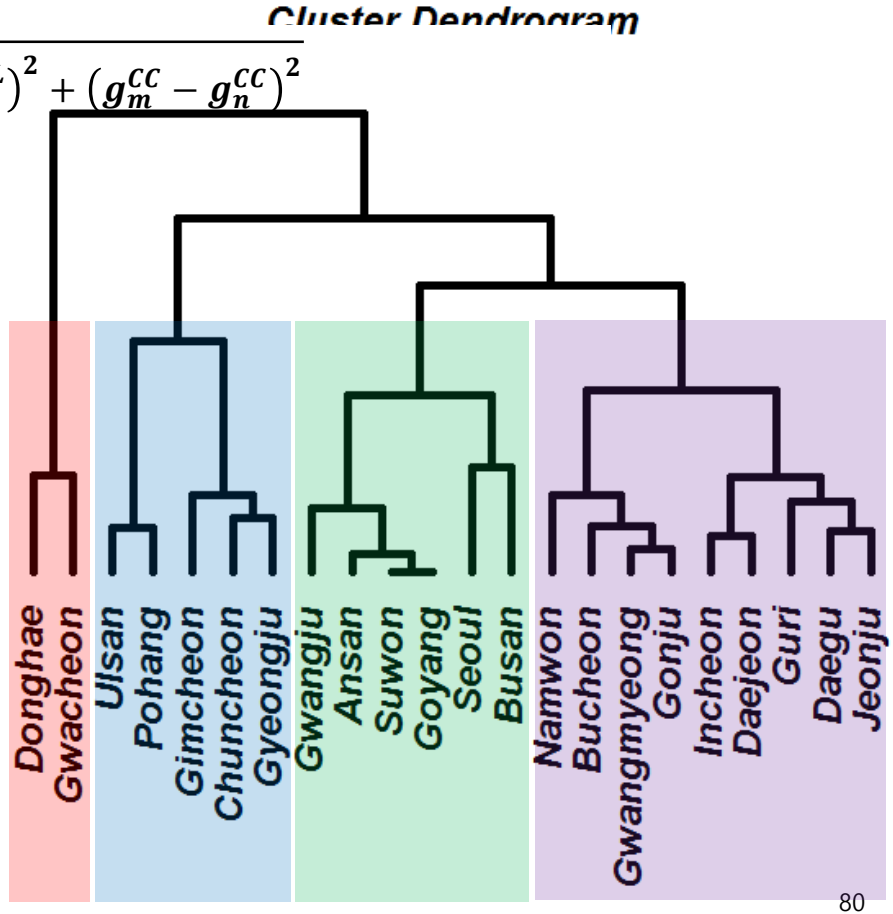
- Red rectangles: Result of **urbanization** (longer total length and more dense roads)
- Blue rectangle: BCs have *positive correlation* with the city's infrastructure size
- Green rectangle: CC has *negative correlation* with the city's infrastructure size, but positive correlation with the land size

Classification: Dendrogram

- Define the **distance matrix**

$$D_{mn} = \sqrt{\left(g_m^{BC\_N} - g_n^{BC\_N}\right)^2 + \left(g_m^{BC\_L} - g_n^{BC\_L}\right)^2 + \left(g_m^{CC} - g_n^{CC}\right)^2}$$

- Do complete-linkage clustering algorithm
- **Classify** into four groups
  1. Donghae, Gwacheon
     - Small town
  2. Ulsan, Pohang; Gimcheon, Chuncheon, Gyeongju
     ① Industrial cities: Ulsan, Pohang
     ② Urban-rural integraed: Gimchoen, Chuncheon, Gyeongju
  3. Gwangju, Ansan, Suwon Goyang; Seoul, Busan
     - Metropolitan cities: Seoul, Busan, Gwangju
     - Captial area: Suwon, Goyang, Ansan
  4. Namwon, Bucheon, Gwangmyeong, Gonju; Incheon, Daejeon, Guri, Daegu, Jeonju



Ongoing Project

1. Mobility model improvement

- Solution to the high deviation issue
- Hybrid model of the gravity and radiation models
- Decision-making process of each movement

2. Street network modeling

- Self-generated city model

3. Dynamics of urban industries

- Change in industrial dynamics for city size and period

Econophysics

Project Members

Complexity in Social System Lab.

Woo-Sung Jung

Min-Woo Ahn

Min-Young Lee

Collaboration

+

College of Business, Chosun Univ.

Gabjin Oh

Introduction

- We investigate the statistical and dynamical properties of ultra high frequency data for an order-driven market
- We focus on the order book of stock market that is lower level than the stock price time series
- We introduce an analogy between the dynamics of the order book and the movement of colloidal particle embedded in the fluid.
  Yoshihiro Yura, Hideki Takayasu, Misako Takayasu, PRL(2014)

- Data set

London Stock Exchange Order Book

2008.08 - 2009.03, 2010.03 - 2009.08

Almost 2500 firms

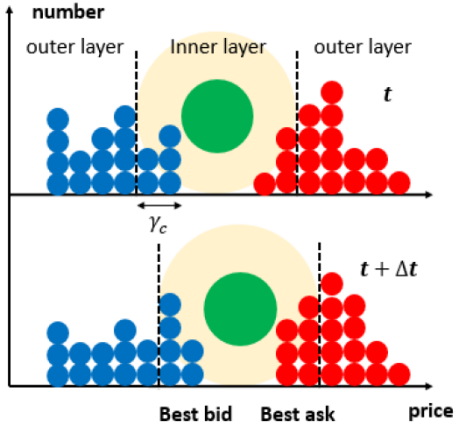
VOD.L VODAFONE GROUP PLC ORD USD0.11 3/7

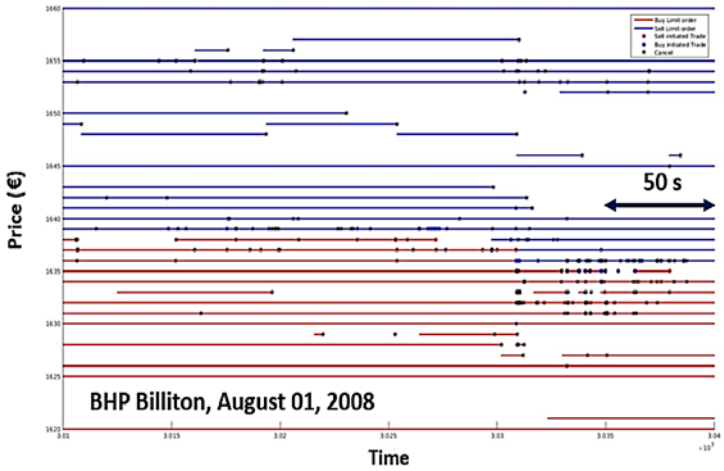
Order Book VOD.L

4		71006	162.9-162.95		79959	9
261		6,825,863	155.42523-167.88226		7,839,197	432
Cumul	Maker	Size	Bid	Ask	Size	Maker	Cumul
4		71006	162.90	162.95	79959		9
10		110436	162.85	163.00	165547		11
11		194292	162.80	163.05	95435		15
14		165796	162.75	163.10	246286		18
16		319872	162.70	163.15	237244		14
10		224002	162.65	163.20	229145		13
7		163907	162.60	163.25	304053		13
4		108296	162.55	163.30	266717		13
3		90365	162.50	163.35	169815		8
25		165282	162.45	163.40	177534		7
1		30702	162.40	163.45	173809		5

Analogy

Financial Brownian Particle





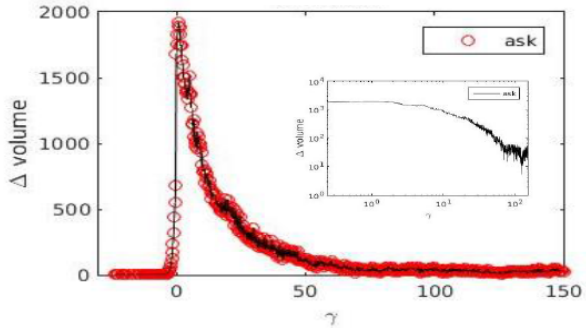
Snapshot of order book (3 min.)

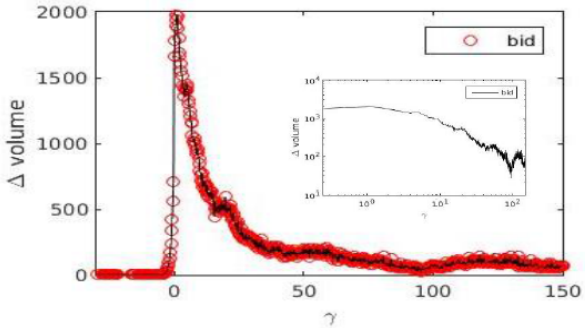
Red/blue bars refer to bid/ask orders in order book

Red/blue circles refer to sell/buy initiated trade

Astros refers to cancellation or expiration of order

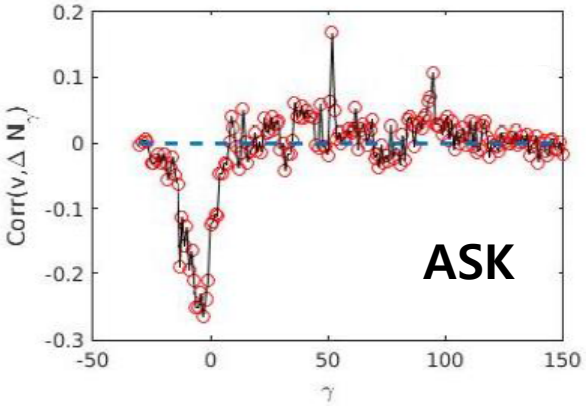
Around best bid/ask price, there are many changes of the nu mber of orders in Order Book. And far from the best prices, th ere are also changes of the number of orders.

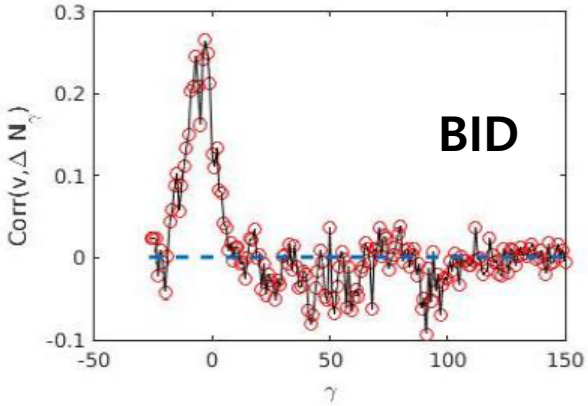


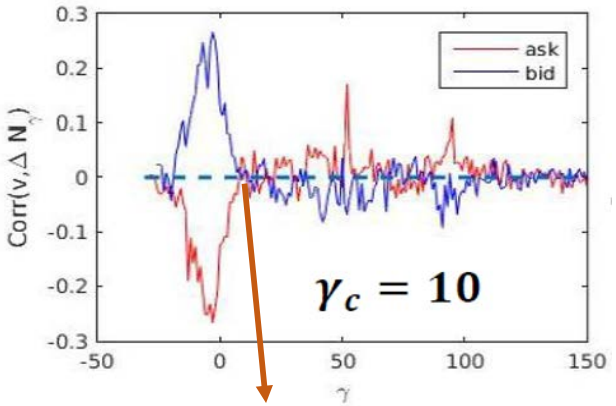


change in the number of particles at depth γ for buy/sell orders. The inserted figures are loglog plot of the change in particle number.

$Corr(v, \Delta N_\gamma)$







Intersecting point:

Criteria of Inner layer & Outer layer

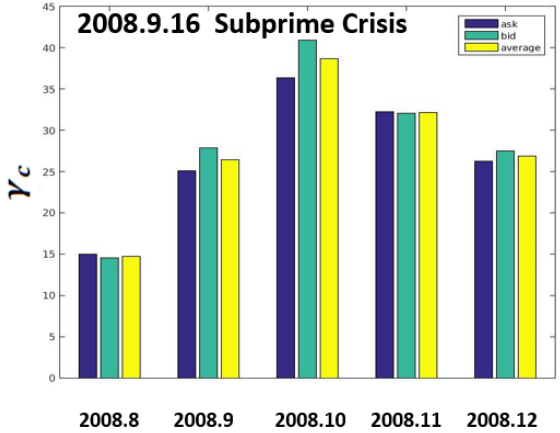
As the colloidal particle moves to the right (price goes up) ,

In Inner layer, # of the buy order increases

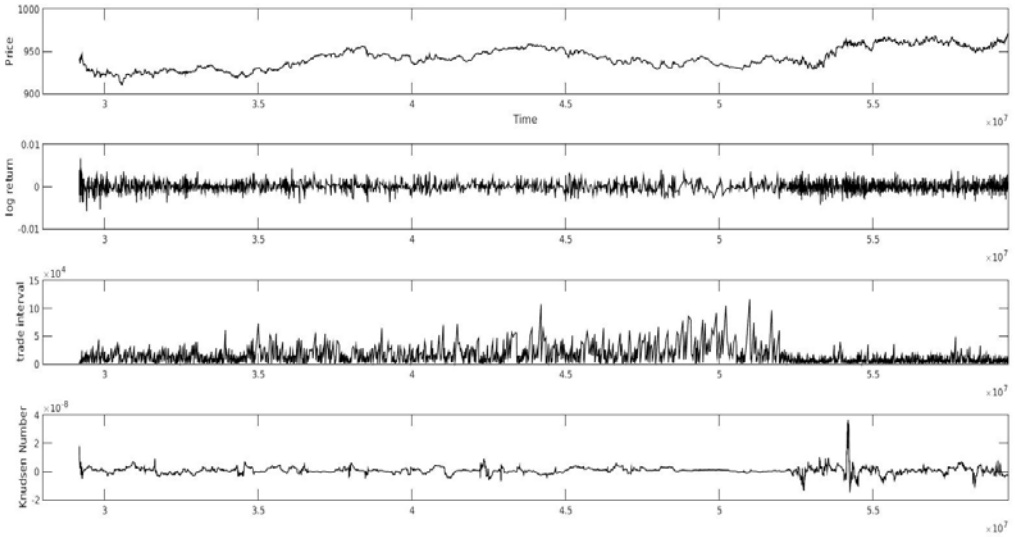
of the buy order decreases

In Outer layer, # of the buy order decreases

of the buy order increases



Variation of the average γ_c during the financial crisis



$$Kn = \frac{L}{\gamma_c}$$

Kn: Knudsen number

L: Mean free path

γ_c: Representative physical length scale

If the Knudsen number(dimensionless) is large,

the mean free path of a molecule is comparable to a length scale of the probl em,

and the continuum assumption of fluid mechanics is no longer a good appro ximation

Knudsen number → Indicator of market collapse or financial crisis (better than volatility)

Ongoing Work

1. Analyzing the dynamics of the fluid particles in the inner layer and the outer layer
2. Modifying the definition of Knudsen number in the Financial Brownian particle
3. Analyzing the dynamics of the Financial Brownian particle according to the firm's characteristics (ex. Market value)
4. Verifying the change of the range of inner layer and Knudsen number during the financial crisis (2008 Subprime Crisis, 2010 Greece de bt crisis)

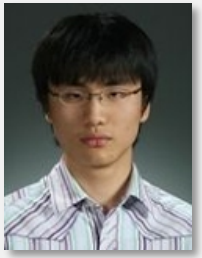
Network & Social Media

Project Members

Complexity in Social System Lab.

Woo-Sung Jung

Min-Woo Ahn



Byoung-Hwa Lee

Collaboration

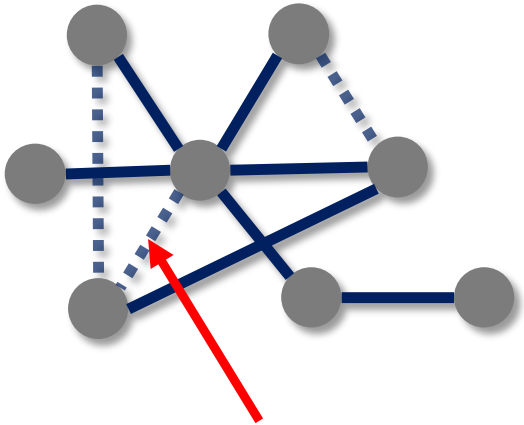
+

College of Business, KAIST

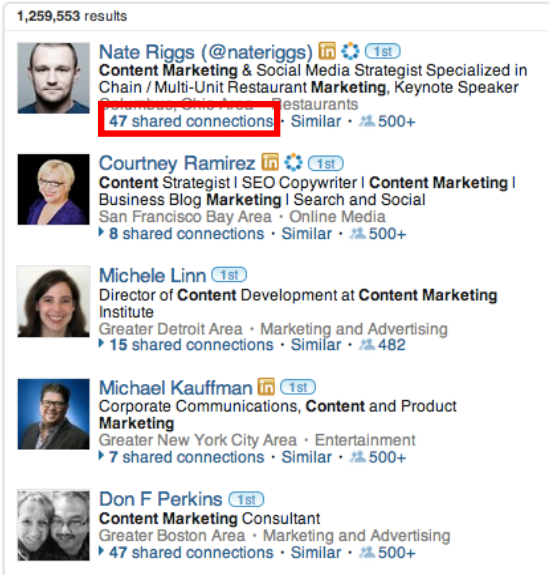
Daegon Cho

Link prediction

- Missing links in complex network

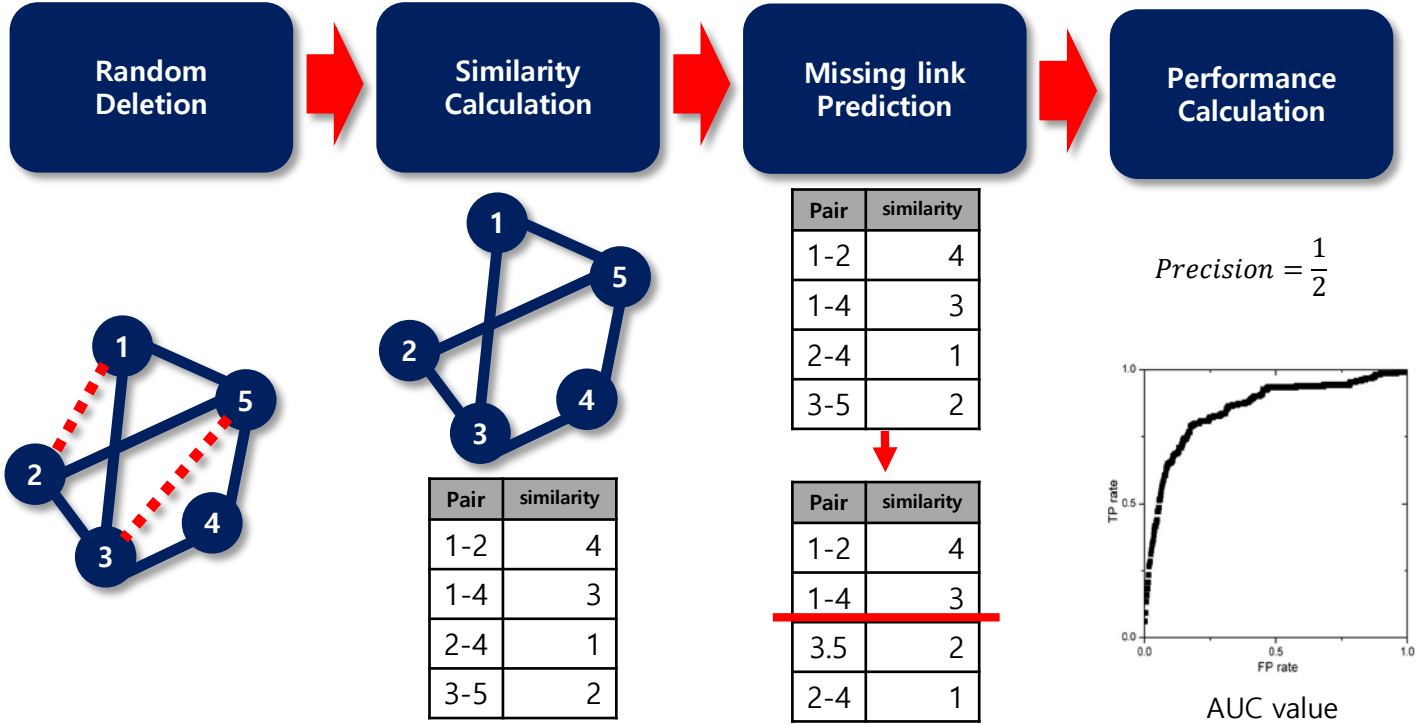


Relation exists, but
omitted in the data



Link prediction

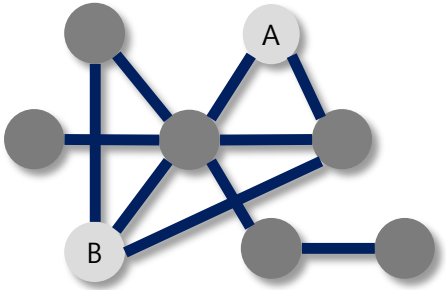
- Overall methodology for link prediction



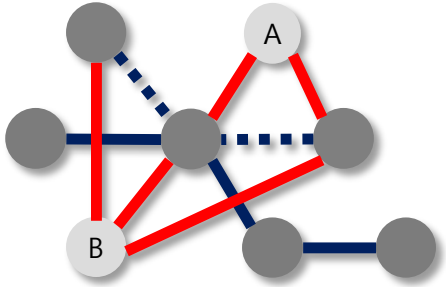
Link prediction

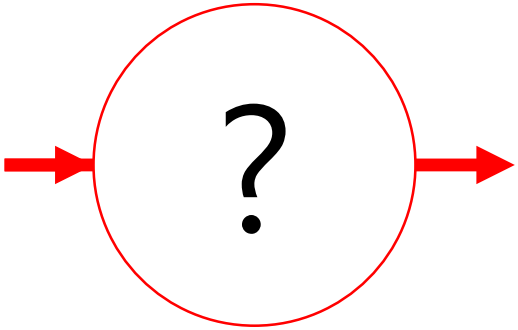
- How they works?

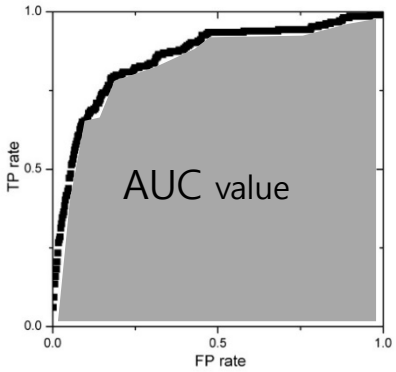
Original Network



Remained Network

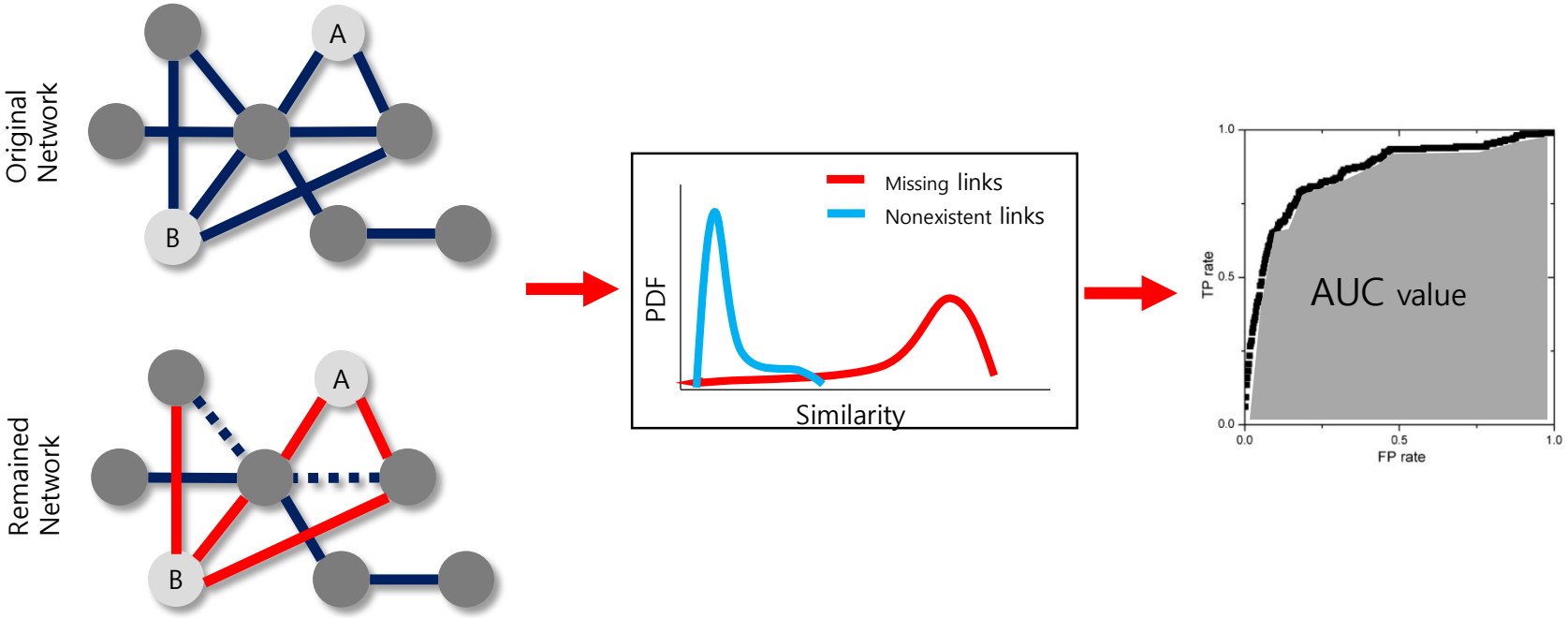






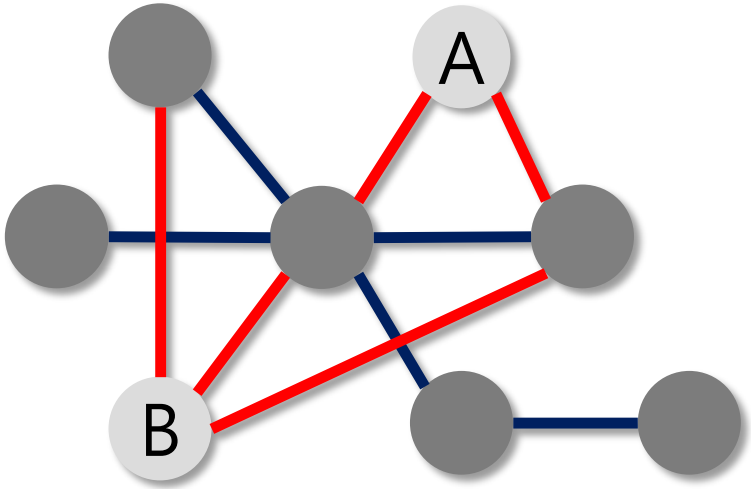
Link prediction

- How they works? -> Distributional analysis



Deletion Operator

- Common-Neighbor index (CN index)
  - Number of common neighbor



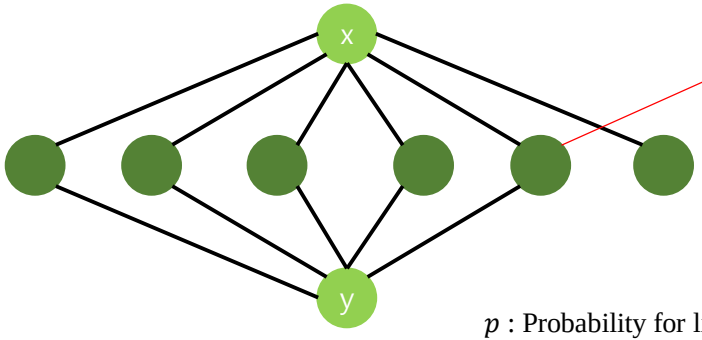
$$CN(A,B) = 2$$

Deletion Operator

- Change of similarity distribution under random deletion
- Transition probability in the case of common neighbor index,

$$P(N \to n, p) = \binom{N}{n} (1-p)^{2n} (2p - p^2)^{N-n}$$

$CN(x, y) = 5$



Probability that remained as a common neighbor of node x and y : $(1-p)^2$

p : Probability for link deletion

Deletion Operator

- $S_D = DS$
  S_D : Similarity distribution after random deletion
  D : Deletion operator matrix
  S : Original similarity distribution

- $$D = \begin{bmatrix} 1 & \binom{1}{0}(2p - p^2) & \binom{2}{0}(2p - p^2)^2 \\ 0 & \binom{1}{1}(1-p)^2 & \binom{2}{1}(1-p)^2(2p - p^2) \\ 0 & 0 & \binom{2}{2}(1-p)^4 \end{bmatrix}$$

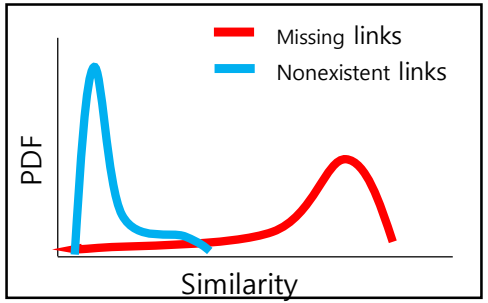
$$D_{ij} = \begin{cases} \binom{j}{i}(1-p)^{2i}(2p - p^2)^{j-i} & (j \geq i) \\ 0 & (j < i) \end{cases}$$

Deletion Operator

- Distribution of CN for nonexistent links and missing links

$$S_{DN} = DS_N, S_{DM} = DS_C$$

S_{DN} : Distribution of CN for nonexistent links after deletion
S_N : Original distribution of CN for nonexistent links
S_{DM} : Distribution of CN for missing links
S_C : Original distribution of CN for connected link



Deletion Operator

- Similarity distributions of remained network is calculated from similarity distributions of original network

- Relationship with those two distribution?

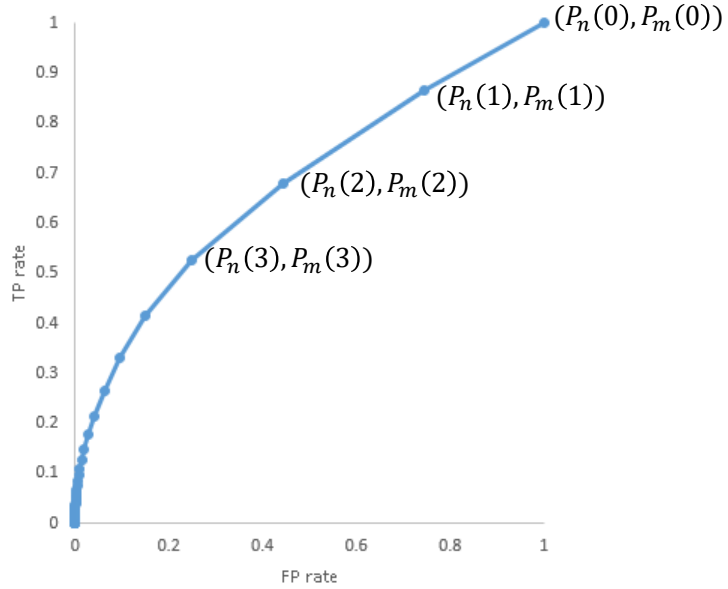
Methodology

- Calculation of accuracy from two distributions
  p_m, p_n : PDF, P_m, P_n : CDF
  (m = missing link, n = nonexistent link)

- For certain threshold s,
  $TP\ rate = P_m(s)$
  $FP\ rate = P_n(s)$

		True class: p	True class: n
Hypothesized class	Y	True Positives	False Positives
	N	False Negatives	True Negatives
Column totals:		P	N

$$\text{tp rate} = \frac{TP}{P} \qquad \text{fp rate} = \frac{FP}{N}$$



Methodology

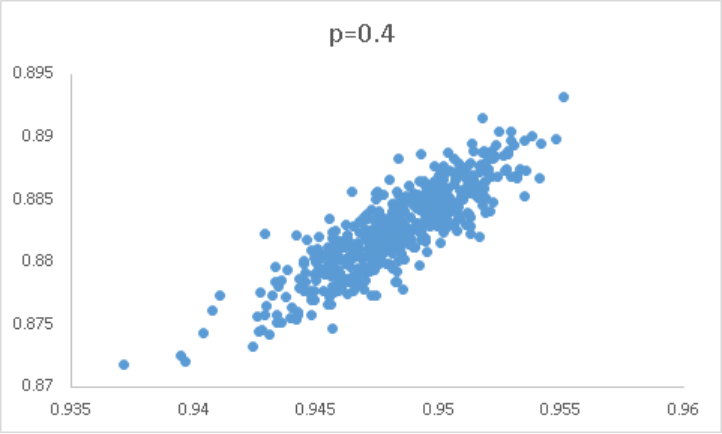
- Correlation with original network information
  - AUC value calculation for S_C, S_N (AUC_{disc})
    : discrimination for connected/unconnected node pairs
  - AUC value calculation for S_{DM}, S_{DN} (AUC_{pred})
    : performance for link prediction process under random deletion
  - Draw scatter plot for two AUC values

$$S_{DN} = DS_N, S_{DM} = DS_C$$

- Test with WS model ensembles

Result

- Test with WS model ensembles (N=1000, <k>=10, 500 ensembles)



- Good link prediction performance is originated from well-discriminated state of link prediction

The 3rd International Workshop on Physics of Social Complexity (PoSCo)

May 27 (Fri), 2016 ~ May 28 (Sat), 2016 / APCTP HQ, Pohang

May 27, Friday		
Time	**Speaker**	**Title**
12:00 - 13:50	**Registration**	
13:50 - 14:00	**Opening** by Woo-Sung Jung	
14:00 - 15:00	Takashi Shimada (The Univ. of Tokyo)	**On the Robustness of Evolving Open Systems**
15:00 - 16:00	Janos Kertesz(Central European Univ.)	**Kinetics of Social Contagion**
16:00 - 17:00	Seung-Woo Son (Hanyang Univ.)	**PageRank centrality on directed network**
17:00 - 18:00	Hiraku Nishimori (Hiroshima Univ.)	**Dynamical aspects of group foraging of ants**
18:00 - 19:00	Hang-Hyun Jo (POSTECH)	**Large Variance and Fat Tail of Damage by Natural Disaster**
19:00 - 21:00	**Banquet**	

May 28, Saturday		
Time	**Speaker**	**Title**
09:00 - 10:00	Nobuyasu Ito (The Univ. of Tokyo & RIKEN AICS)	**Agent simulation of stock markets**
10:00 - 11:00	Seung Ki Baek (Pukyong Nat'l Univ.)	**Combination of tit-for-tat and anti-tit-for-tat remedies problems of tit-for-tat**
11:00 - 12:00	Akira Namatame (Nat'l Defense Academy)	**TBA**
12:00 - 14:00	**Lunch & Discussion**	
14:00 - 15:00	Yohsuke Murase (RIKEN AICS)	**Universality in open evolving systems**
15:00 - 16:00	Kousuke Yakubo (Hokkaido Univ.)	**Self-Organization of fractal networks**
16:00 - 17:00	Naoki Yoshioka (RIKEN AICS)	**Macroscopic behavior and stability in urban traffic network**
17:00 - 18:00	Woo-Sung Jung (POSTECH)	**Complexity Analysis of Social System: Transportation and Bibliometrics**

APEC-SSS 2016

- Asia Pacific Econophysics Conference 2016
  - Big Data Analysis and Modeling towards Super Smart Society

  - Date: August 24th-26th
  - Place: The University of Tokyo, Japan
  - http://www.apec-sss2016.org

- APEC 2017: India

2nd JSPS-NRF Workshop

- August 27th-28th
  - APEC-SSS 2016: August 24th-26th
- Where?
  - Tokyo

NetSci 2016

NetSci

Seoul, South Korea
May 30–June 3, 2016

International School and Conference on Network Science

Room (Capacity)	**MON** AM	**MON** PM	**TUE** AM	**TUE** PM
Crystal Ballroom A	(http://scholar.harvard.edu/yyl/network-control-2016) Yang-Yu Liu, Gang Yan, Marco Tulio Angulo, Pau Vilimelis Aceituno **Controlling Complex Networks**		(http://danlarremore.com/sinm2016) Bailey Fosdick, Abigail Jacobs, Daniel Larremore, Aaron Clauset, **Statistical Inference for Network Models**	
Geumkang A	(http://netsci2016-nsra.net/) Byungnam Kahng, Zengru Di, Naoki Masuda, **Network Science researches in Asia: Fundamentals**		(http://netsci2016-nsra.net/) Byungnam Kahng, Zengru Di, Naoki Masuda, **Network Science Researches in Asia: Applications**	(http://netsci2016-nsra.net/) KAST Public Lectures
Geumkang B				(http://tinyurl.com/netscied5) Hiroki Sayama, **NetSciEd 5: Satellite Symposium on Network Science and Education**
Dongkang A	(http://geotoponets2016.weebly.com/) Maksim Kitsak, Dmitri Krioukov, Giovanni Petri, **Network Geometry and Topology Workshop**	(http://entropy.kaist.ac.kr/wordpress/?page_id=245) Naoki Masuda, Juyong Park, **Competition Networks and Centrality**	(http://www.complexity.es/netsci2016brain) Danielle Bassett, Javier Martín Buldú,Mario Chávez, Fabrizio de Vico Fallani, Andrea Gabrielli, Johann H. Martínez, David Papo, Qawi K. Telesford, Robin W. Wilkins, **Brain networks**	
Dongkang B	(http://complexdata.businesscatalyst.com/)Sang Hoon Lee, Taro Takaguchi, Renaud Lambiotte, Ingo Scholtes, Jinhyuk Yun, **When Complex Networks Meet Complex Data: Higher-Order Models in Network Science**		(http://www.quantifysuccess.org/netsci2016/) Tao Jia, Roberta Sinatra, **Quantifying success**	
Dongkang C	(https://www.apctp.org/plan.php/netimp2016) Pan-Jun Kim, Cheol-Min Ghim, Junhyo Jo, Daehee Hwang, **I am My Phenotypes: Bringing Biological Networks into Phenotypic Contexts**	(http://netsci2016-tech.weebly.com/) James McNerney, Hyejin Youn, Ceasar Hidalgo, Iyad Rahwan **Networks and Technology Evolution**	(http://netonets.org/events/netonets2016/) Gregorio D'Agostino, Michele Coscia, **Netonets2016**	
Dongkang D	(https://sites.google.com/site/socialconnectome/) Hang-Hyun Jo,Woo-Sung Jung, Nobuyasu Ito, Jari Saramäki, **Social Connectome: The Anatomy of Social Networks and its Modeling**		(http://barabasilab.com/netmed16/) Amitabh Sharma, Kwang-Il Goh, Marc Santolini, **Multiscale Characterization of the Human Diseases by Multinetworks**	

CCS 2016

- Conference on Complex Systems
  - September 19th-22nd
  - Amsterdam, The Netherlands

- Satellite
  - 25. Hot Topics in the Study of Complex Systems in Asia

Japan-Korea

Benjamin Lee Professorship

Overview

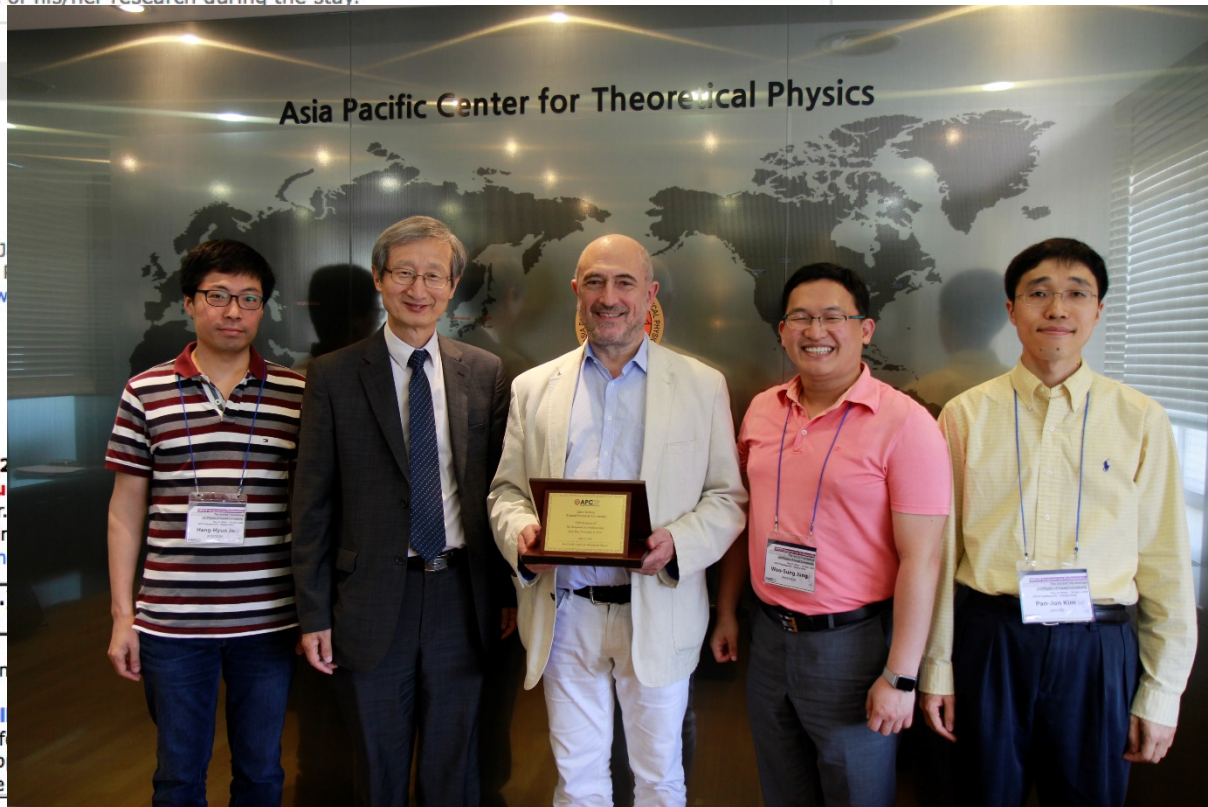
Benjamin Lee distinguished professorship is created in honor of Korea's foremost theoretical physicist, late Benjamin Lee, who had a distinguished career in particle physics theory. The program is intended to invite a theoretical physicist of international prominence to stay at APCTP for an extended period. The visit is expected to provide opportunities for the domestic scientists and graduate students to interact with an world-caliber theoretical physicist in their fields of study. The Benjamin Lee professor may give lecture sessions and/or organize small workshops built around the theme of his/her research during the stay.

2016

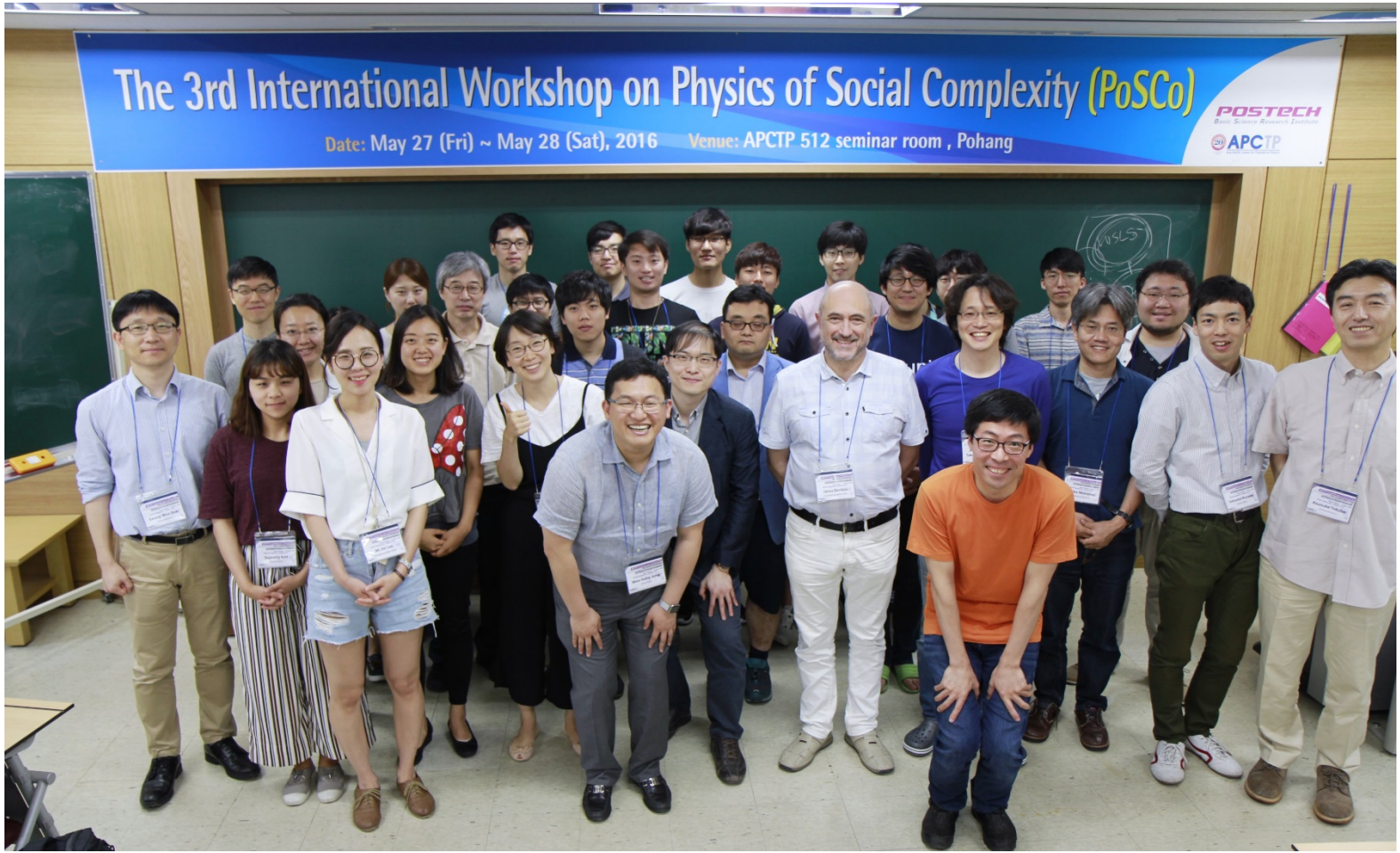
Professor J
Statistical
https://ww

• **Period of visit: May 23 ~ June 4, 2**
<Benjamin Lee Professorship Lectu
▶Date: Date: May 25 (Wed.)- 26 (Thur.
▶Place: APCTP Seminar room (Hogil Kir
▶Program: https://www.apctp.org/plan

May 25 (Wed. **10:00 a.m.**
Lecture I Complex Networks: An in
APCTP&POSTECH Col Tracing people's digital f A Statistical Physics Ap Social Science




2016 APCTP Benjamin Lee Professorship Lecture Series
Date: May 25th (Wed.) – May 26th (Thur.), 2016
Venue: APCTP 512 seminar room, Pohang
APCTP


The 3rd International Workshop on Physics of Social Complexity (PoSCo)
Date: May 27 (Fri) ~ May 28 (Sat), 2016
Venue: APCTP 512 seminar room , Pohang
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Thank you