# 計量書誌学と情報工学の融合による大規模学術・産業情報の分析

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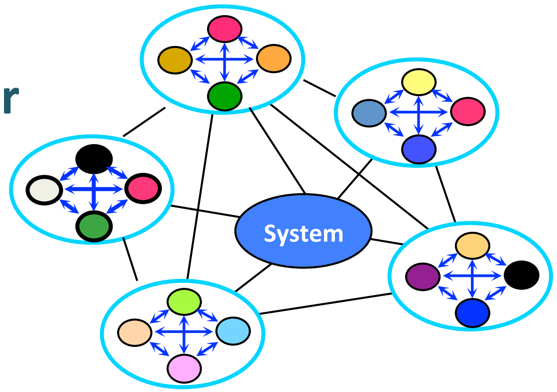
イノベーション政策研究センター

# Innovation Policy Research Center

**Activities – 3 pillars**

**1. Innovation & Technology Management Research**

- Develop new methodologies
  (Scientometrics, Information Retrieval etc.)
- Applied research (Roadmap, Process design etc.)
- Interdisciplinary research (Sustainability, Gerontology)




**2. Workshop, Conference, Seminar, Technology Transfer**

- International Conference, Monthly seminar
- Web system
- Discussion Paper Series

**3. International Network and Collaboration**

OECD, IEA, APEC, ERIA etc.

# Our focus of Research

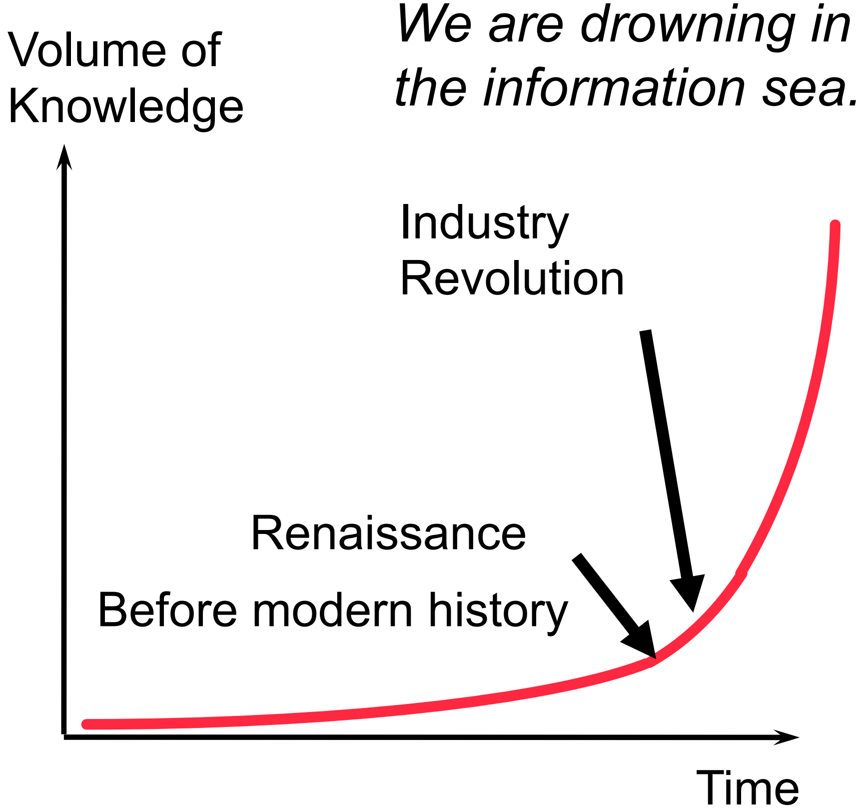
- US Government "Science of Science & Innovation policy" -

| | Field | Models/Tools | Maturity | Query | Scope | # papers |
|---|---|---|---|---|---|---|
| Quantitative Analysis (Deterministic) | Economics | Econometric | | Econometric*, | SSCI | 11,189 |
| | | Risk Modeling | | Risk* and Model* | ECONOMICS | 8,594 |
| | | Options Modeling | | Option* and Model*, | SSCI | 8,043 |
| | | Cost Benefit | | Cost* and Benefit* | SCI&SSCI | 53,487 |
| | | Cost Effectiveness | | | | |
| Quantitative Analysis (Stochastic) | | Agent Based | | Agent based | SCI&SSCI | 4,381 |
| | | System Dynamics | | System dynamics | SCI&SSCI | 4,361 |
| Qualitative Analysis | Social studies | Case Studies | | | | |
| | | Peer/Expert Review | | | | |
| | | Delphi | | | | |
| | | Strategic/Logic | | | | |
| Visualization Tools | **IT, WEB** | Network Analysis | | Network analysis | SCI&SSCI | 4,709 |
| | | Visual Analytics | | Visualization | CS&IS | 7,811 |
| | | Science Mapping | | - | JISIS(T), Scientometrics , J Infometrics | 5,670 |
| | | Scientomenrics | | | | |
| Data Collection Tools | **Statistics , WEB** | Survey | | | | |
| | | Web scraping | | Web | CS&IS | 23,832 |
| | | Administration Data | | | | |
| | | Data Mining | | Data mining | SCI&SSCI | 15,473 |

# Fundamental challenges we face

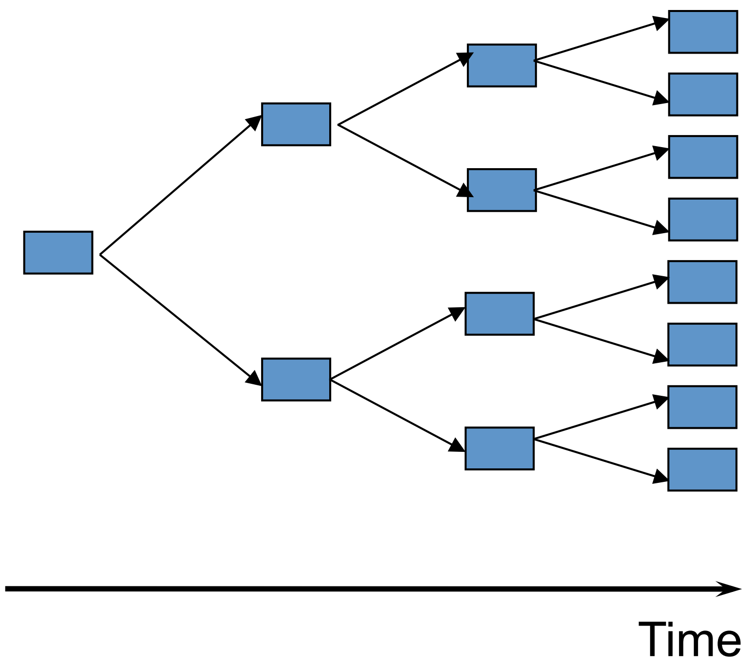
- **Exponential growth of knowledge**

*We are drowning in the information sea.*




- **Segmentation & Specialization**

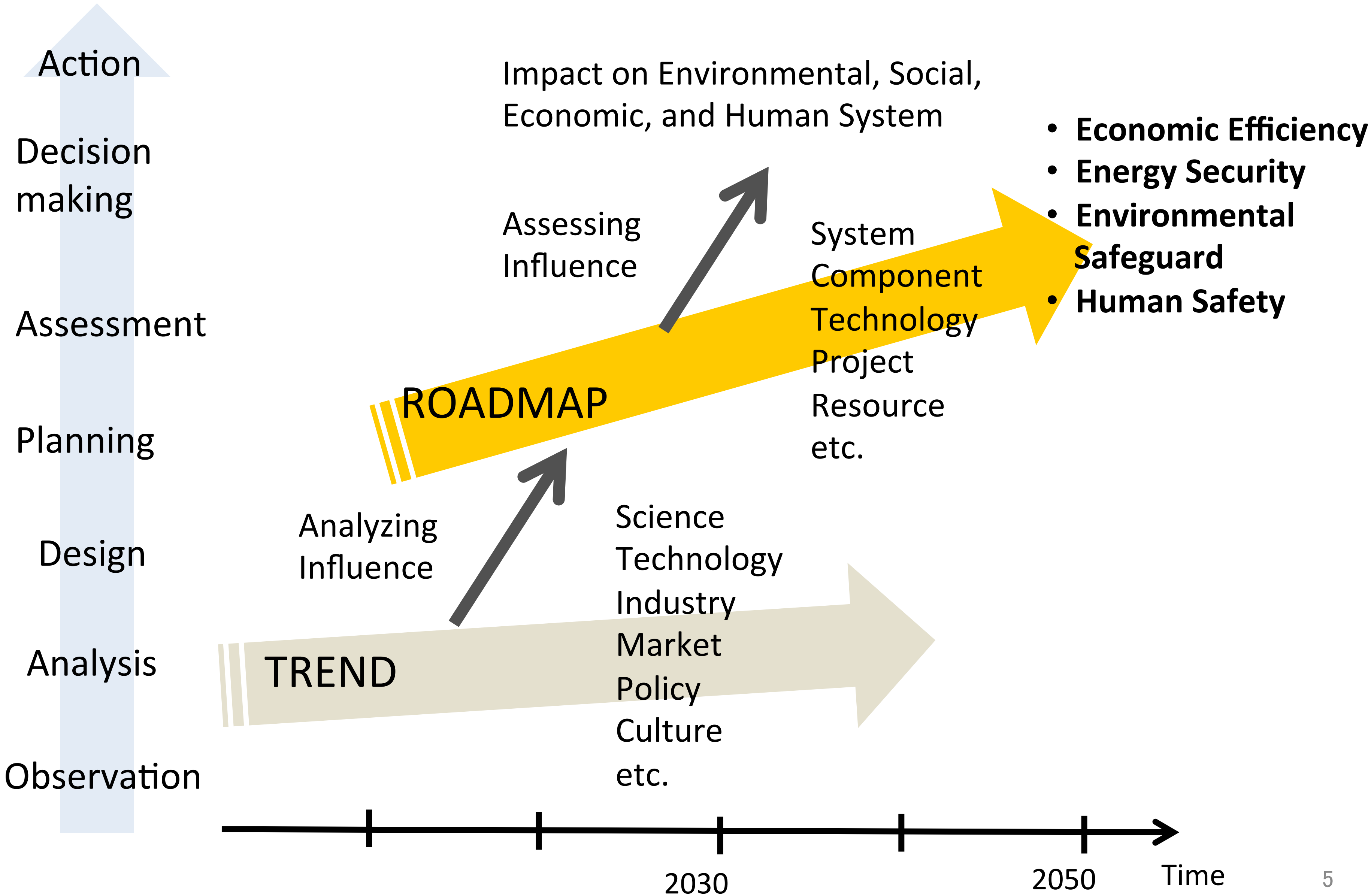
*Prerequisite to catch up with the pace of development*




- **Complexity of Social Issues.**

Ex) Sustainability, Aging Society

# Short-, mid-, and long-term roadmapping



# Limitation of expert-based approach

- Historically, such tasks have been handled by experts, such as by the so-called Delphi method initiated by the Rand Corporation of the US in the 1950s. These are known as the **social or expert based approach**.

- However, it becomes more **difficult** to create technological overview using an **expert-based approach** because:

  **1)** the amount of academic knowledge is increasing so fast that no expert can capture the entire knowledge structure of a specific knowledge domain;

  **2)** the expert-based approach is expensive and time consuming;

  **3)** the generally accepted definition of a targeted research field is sometimes lacking.

- Therefore, we have developed a **computer-based approach,** which analyzes explicit knowledge such as journal papers and letters.

# Computational Intelligence for R&D management

## Non-structured Information

**Vast amount of**

- **Paper**
- **Patent**
- **Researcher**
- **Organization**

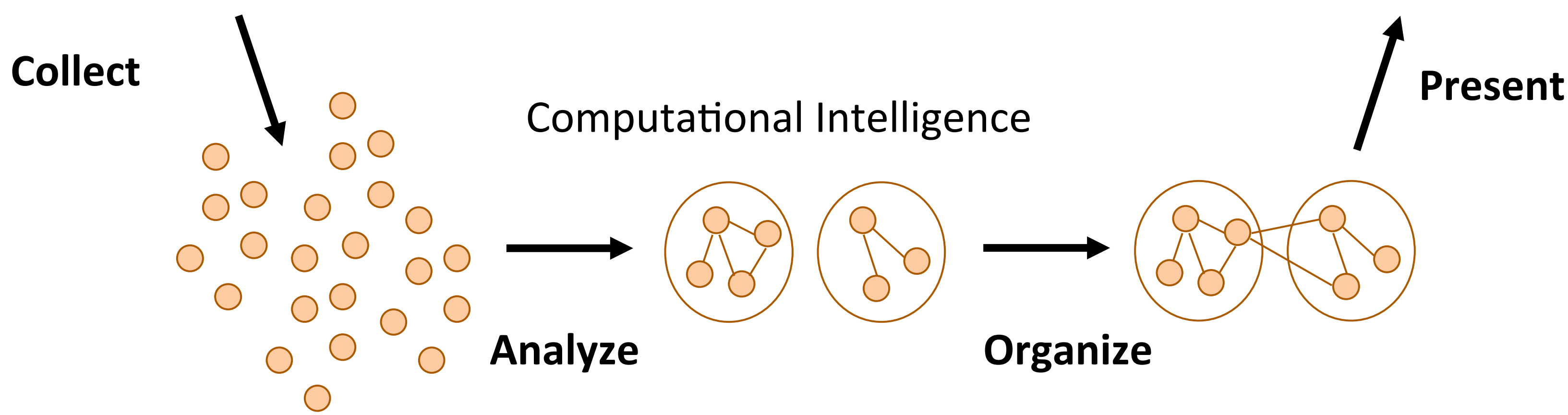
**etc.**

## Structured Information

**Observation of …**

- **Trend of Science and Technology**
- **Emerging Research Field**
- **Complex Industrial Structure**
- **Collaboration Network**

**etc.**



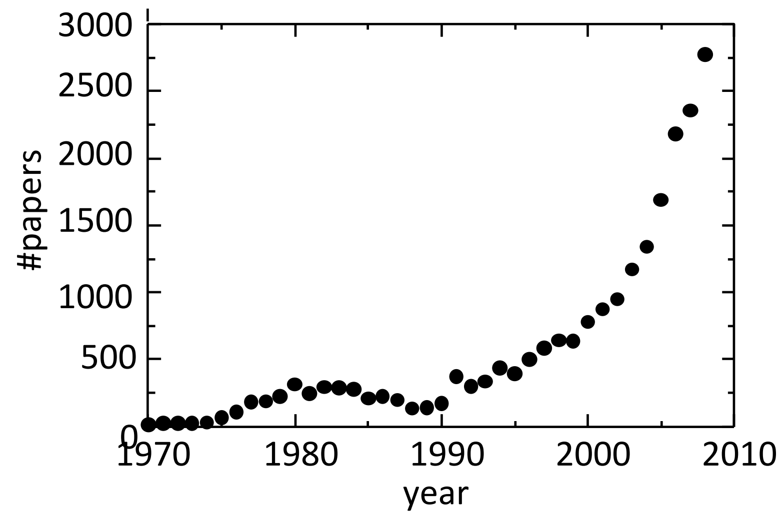
# Methodology of academic landscape

**Target selection**

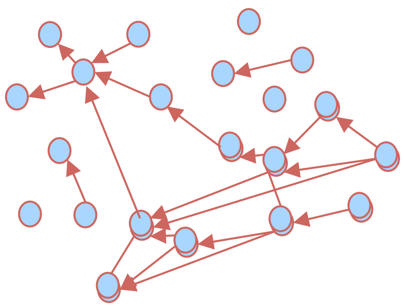
Ex. Solar Cell

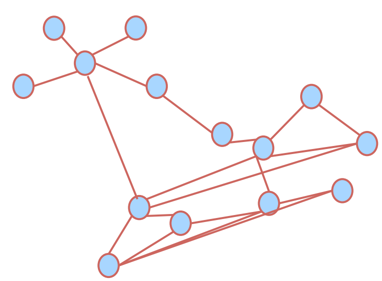
**Corpus construction**

Ex.Query = "Solar Cell*" or Photovolt*
Time span = 1959-2009




**Citation Network Analysis**

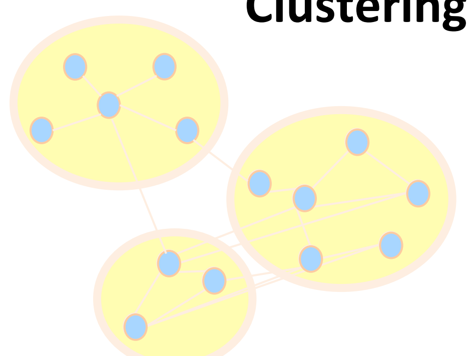




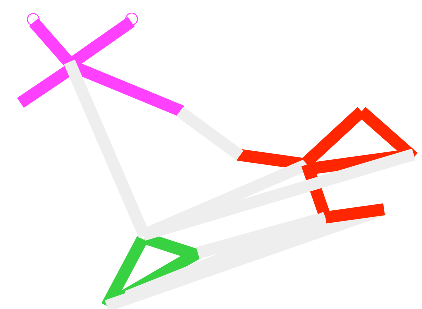
Kajikawa et al., *TFSC* (2008, 2009)
Shibata et al., *Technovation* (2008)
Sakata et al., *TFSC* (2012)

**Identification of characteristics of clusters with experts**

**Clustering**



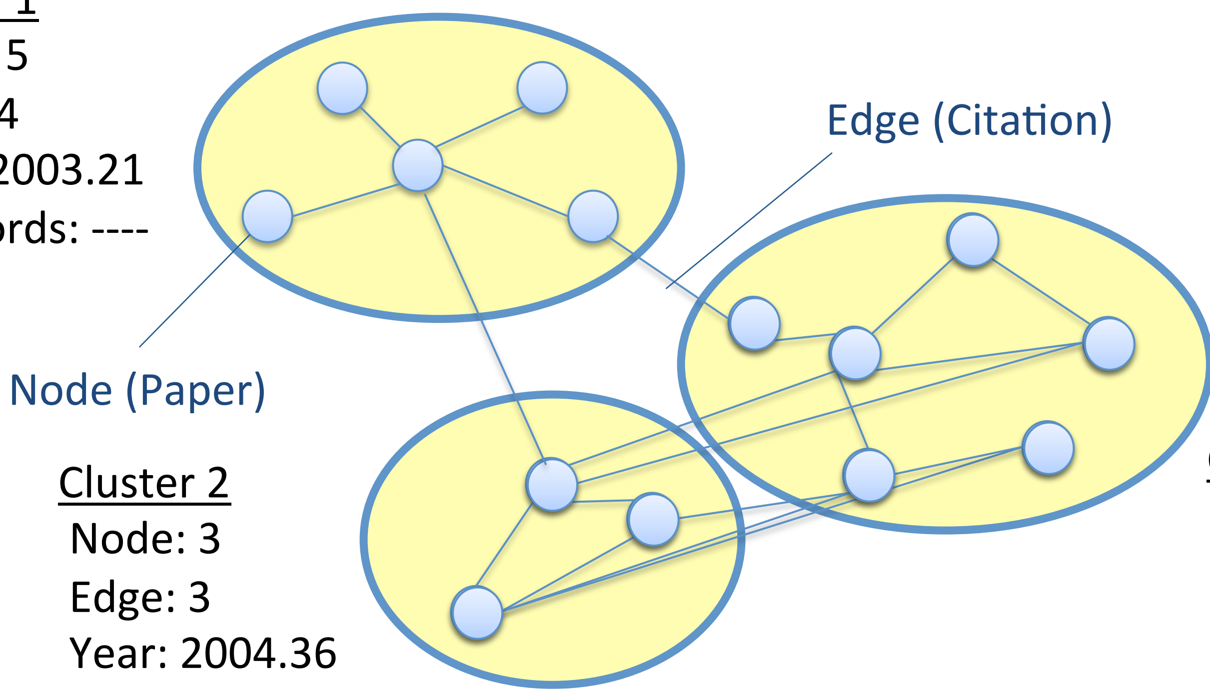
**Visualization**



# Citation Network Analysis

- Node： Papers in the largest-graph component data
- Edge： Citation between Papers
- Year： Average Publication Year in the cluster
- Keywords: Characteristic words in the cluster

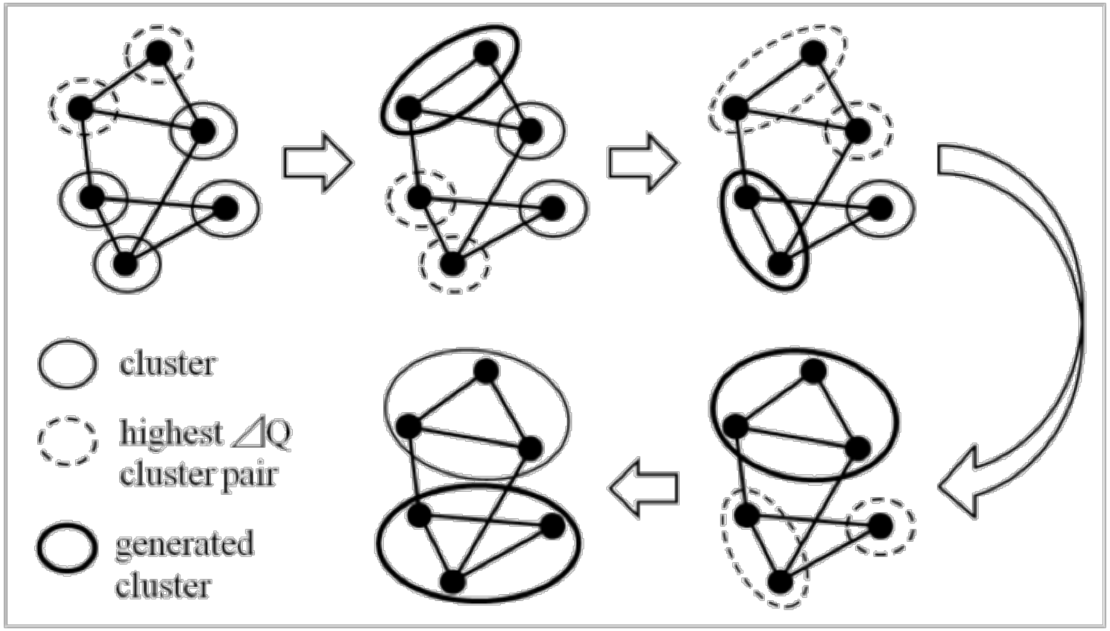
Cluster 1
Node: 5
Edge: 4
Year: 2003.21
Keywords: ----




Cluster 2
Node: 3
Edge: 3
Year: 2004.36
Keywords: ----

Cluster 3
Node: 6
Edge: 6
Year: 2007.96
Keywords: ----

# Network Clustering (Newman M.E.J 2004)




$$Q = \sum_i (w_{ii} - a_i^2)$$

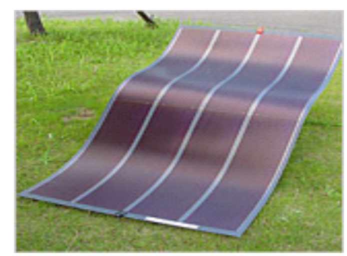
$$a_i = \sum_j w_{ij}$$

$w_{ij}$: the possibility of the weights of edges in the network that connected nodes in cluster s to those in cluster j

- Connect clusters sparsely and extract clusters within which nodes are connected densely is cut.
- A high value of *Q* represents good community division where only dense edges remain within clusters and sparse edges between clusters are cut off, and
- *Q = 0* means that a particular division gives no more within-community edges.

# Academic Landscape System

- Web-based system **http://academic-landscape.com**
  - Python scripts, libraries, Web server and Database on a Linux server
- Automatically analyze the large volume of scientific paper and patent data
  - Input:
    - Records of Web of Science database (paper) or Thomson Innovation database (patent)
  - Creating a citation network
    - Direct citation, co-citation, and bibliographic coupling
  - Analyzing a citation network
    - Clustering and Network Centrality
  - Analyzing text information
    - Keyword and Topic extraction
  - Visualization
    - Statistics
      - Publication years, Countries, Journals, Researchers, etc.,
    - Citation network
    - Heatmap (similarity among clusters)



**a3621: solar cell**

Web of Science · Direct Citations · No weights / Co-occurrence freq. · Modularity maximization · d3664: solar cell · tanunyav created at 2013年07月17日

Download · Delete

List | Overview | Graph tool | Heatmap | Log

Derive a new dataset

| Summary | |
|---|---|
| Ave. year | 2001.7 |
| # of nodes | 17,096 |
| # of edges | 92,738 |

| Keywords | |
|---|---|
| film | 0.0027 |
| silicon | 0.0023 |
| layer | 0.0018 |
| deposition | 0.0016 |
| thin film | 0.0015 |

Countries

| Institutes | |
|---|---|
| Natl Renewable Energy Lab | 446 |
| Univ New S Wales | 325 |
| Hahn Meitner Inst Berlin Gmbh | 263 |
| Chinese Acad Sci | 262 |
| Fraunhofer Inst Solar Energy Syst | 218 |

| Journals | |
|---|---|
| SOLAR ENERG MATER SOLAR CELLS | 1946 |
| THIN SOLID FILMS | 1596 |
| J APPL PHYS | 1340 |
| APPL PHYS LETT | 1101 |
| PROG PHOTOVOLTAICS | 546 |

| Authors | |
|---|---|
| Green, MA | 163 |
| Schock, HW | 144 |
| Lux-Steiner, MC | 128 |
| Yamada, A | 122 |
| Schropp, REI | 122 |

| Publication years | |
|---|---|
| 2011 | 2155 |
| 2010 | 1676 |
| 2009 | 1403 |
| 2008 | 1038 |
| 2006 | 960 |

Cluster 1 (17096 fac | Search | Page 1 of 17,096 facets

**Progress toward 20% efficiency in Cu(In,Ca)Se-2 polycrystalline thin-film solar cells**
Contreras, MA et al, *PROG PHOTOVOLTAICS*, V7, P311 (1999) — Cluster 1 · Within-cluster cites 490 · Detail

**Authors** Contreras, MA and Egaas, B and Ramanathan, K and Hiltner, J and Swartzlander, A and Hasoon, F and Noufi, R
**Countries** USA
**Institutes** Colorado State Univ, NREL
**Abstract** This short communication reports on achieving 18.8% total-area conversion efficiency for a ZnO/CdS/Cu(In,Ga)Se-2/Mo polycrystalline thin-film solar cell. We also report a 15%-efficient, Cd-free device fabricated via physical vapor deposition methods. The Cd-free cell includes no buffer layer, and it is fabricated by direct deposition of ZnO on the Cu(In,Ga)Se-2 thin-film absorber. Both results have been measured at the National Renewable Energy Laboratory under standard reporting conditions (1000 W/m(2), 25 degrees C, ASTM E 892 Global). The 18.8% conversion efficiency represents a new record for such devices (Notable Exceptions) and makes the 20% performance level by thin-film polycrystalline materials much closer to reality. We allude to rite enhancement in performance of such cells as compared to previous record cells, and we discuss possible and realistic routes to enhance the performance reward the 20% efficiency level. Published in 1999 by John Wiley & Sons, Ltd. This article is a US government work and is in the public domain in the United States.

**19.9%-efficient ZnO/CdS/CuInGaSe2 solar cell with 81.2% fill factor**
Repins, I et al, *PROG PHOTOVOLTAICS*, V16, P235 (2008) — Cluster 1 · Within-cluster cites 343 · Detail

**Authors** Repins, I and Contreras, MA and Egaas, B and DeHart, C and Scharf, J and Perkins, CL and To, B and Noufi, R
**Countries** USA
**Institutes** Natl Renewable Energy Lab
**Abstract** We report a new record total-area efficiency of 19.9% for CuInGaSe2-based thin-film solar cells. Improved performance is due to higher fill factor. The device was made by three-stage co-evaporation with a modified surface termination. Growth conditions, device analysis, and basic film characterization are presented. Published in 2008 by John Wiley & Sons, Ltd.

**Properties of 19.2% efficiency ZnO/CdS/CuInGaSe2 thin-film solar cells**
Ramanathan, K et al, *PROG PHOTOVOLTAICS*, V11, P225 (2003) — Cluster 1 · Within-cluster cites 317 · Detail

**Increasing the efficiency of ideal solar cells by photon induced transitions at intermediate levels**
Luque, A et al, *PHYS REV LETT*, V78, P5014 (1997) — Cluster 1 · Within-cluster cites 282 · Detail

**Coaxial silicon nanowires as solar cells and nanoelectronic power sources**
Tian, BZ et al, *NATURE*, V449, P885 (2007) — Cluster 1 · Within-cluster cites 259 · Detail

**THIN-FILM CDS/CDTE SOLAR-CELL WITH 15.8-PERCENT EFFICIENCY**
BRITT, J et al, *APPL PHYS LETT*, V62, P2851 (1993) — Cluster 1 · Within-cluster cites 233 · Detail

**Diode (characteristics in state-of-the-art ZnO/CdS/Cu(In(1-x)Gax)Se-2 solar cells**
Contreras, MA et al, *PROG PHOTOVOLTAICS*, V13, P209 (2005) — Cluster 1 · Within-cluster cites 211 · Detail

**Authors** Contreras, MA and Ramanathan, K and AbuShama, J and Hasoon, F and Young, DL and Egaas, B and Noufi, R
**Countries** USA
**Institutes** Natl Renewable Energy Lab
**Abstract** We report a new state of the art in thin-film polyctystalline Cu(In, Ga)Se-2-based solar cells with the attainment of energy conversion efficiencies of 19.5 %. An analysis of the performance of Cu(InGa)Se-2 solar cells in terms of some absorber properties and other derived diode parameters is presented. The analysis reveals that the highest-performance cells can be associated with absorber bandgap values of similar to 144eV, resulting in devices with the lowest values of diode saturation current density (similar to 3 x 10(-8) mA/cm(2)) and diode quality factors in the range 1-30 < A < 1.35. The data presented also support arguments of a reduced space charge region recombination as the reason for the improvement in the performance of such devices. In addition, a discussion is presented regarding the dependence of performance on energy bandgap, with an emphasis on wide-bandgap Cu(In,Ga)Se-2 materials and views toward improving efficiency to > 20 % in thin-film polycrystalline Cu(InGa)Se-2 solar cells. Published in 2005 by John Wiley W Sons, Ltd.

**Intrinsic microcrystalline silicon: A new material for photovoltaics**
Vetterl, O et al, *SOLAR ENERG MATER SOLAR CELLS*, V62, P97 (2000) — Cluster 1 · Within-cluster cites 208 · Detail

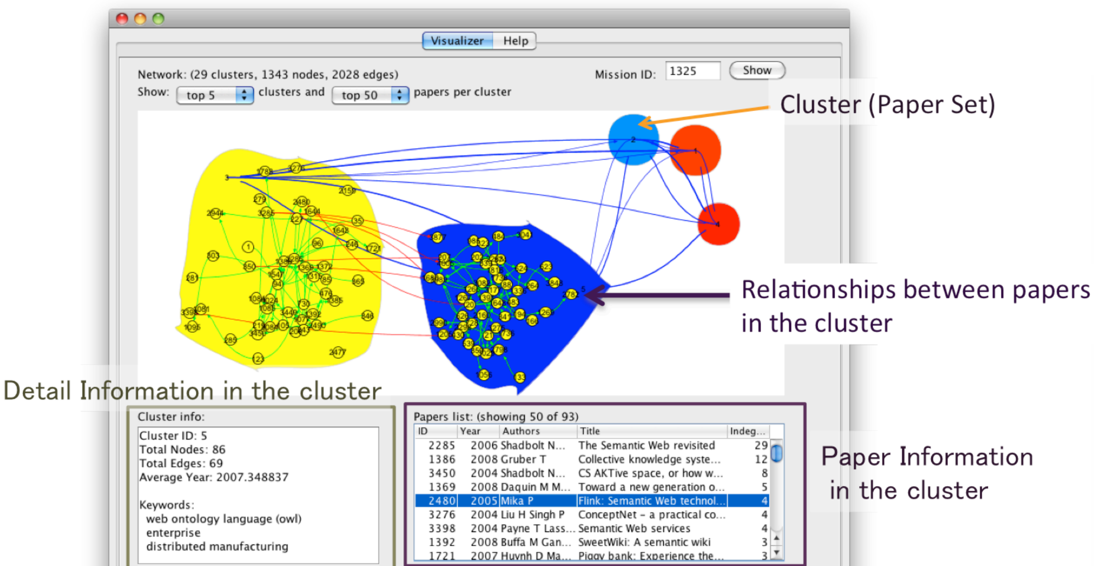
**Thin film deposition methods for CuInSe(2) solar cells**
Kemell, M et al, *CRIT REV SOLID STATE MAT SCI*, V30, P1 (2005) — Cluster 1 · Within-cluster cites 205 · Detail

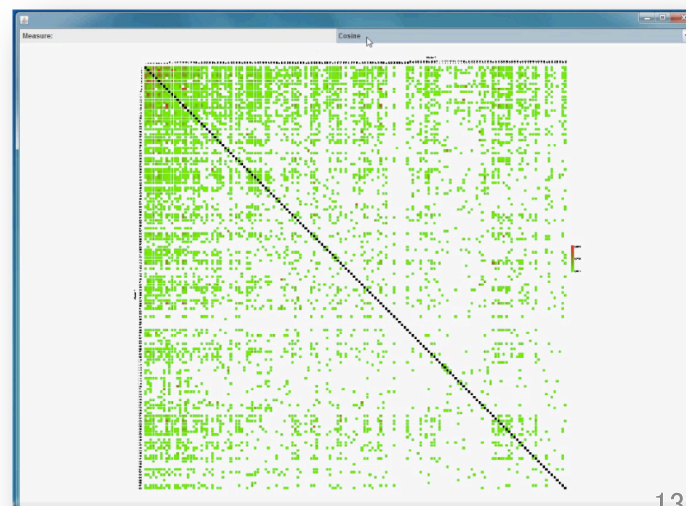
**Electronic properties of Cu(In,Ga)Se-2 heterojunction solar cells-recent achievements, current understanding, and future challenges**
Rau, U et al, *APPL PHYS A-MAT SCI PROCESS*, V69, P131 (1999) — Cluster 1 · Within-cluster cites 197 · Detail

**Authors** Rau, U and Schock, HW
**Countries** Germany
**Institutes** Univ Stuttgart
**Abstract** The recent achievements of high-efficiency Cu(In,Ga)Se-2 heterojunction solar cells are reviewed with a special focus on the understanding of the electronic transport properties of the devices. We discuss the basic limitations of the device performance, the present understanding of electronic device analysis, as well as the role of intrinsic defects and of the interfaces for the performance of the solar cells.

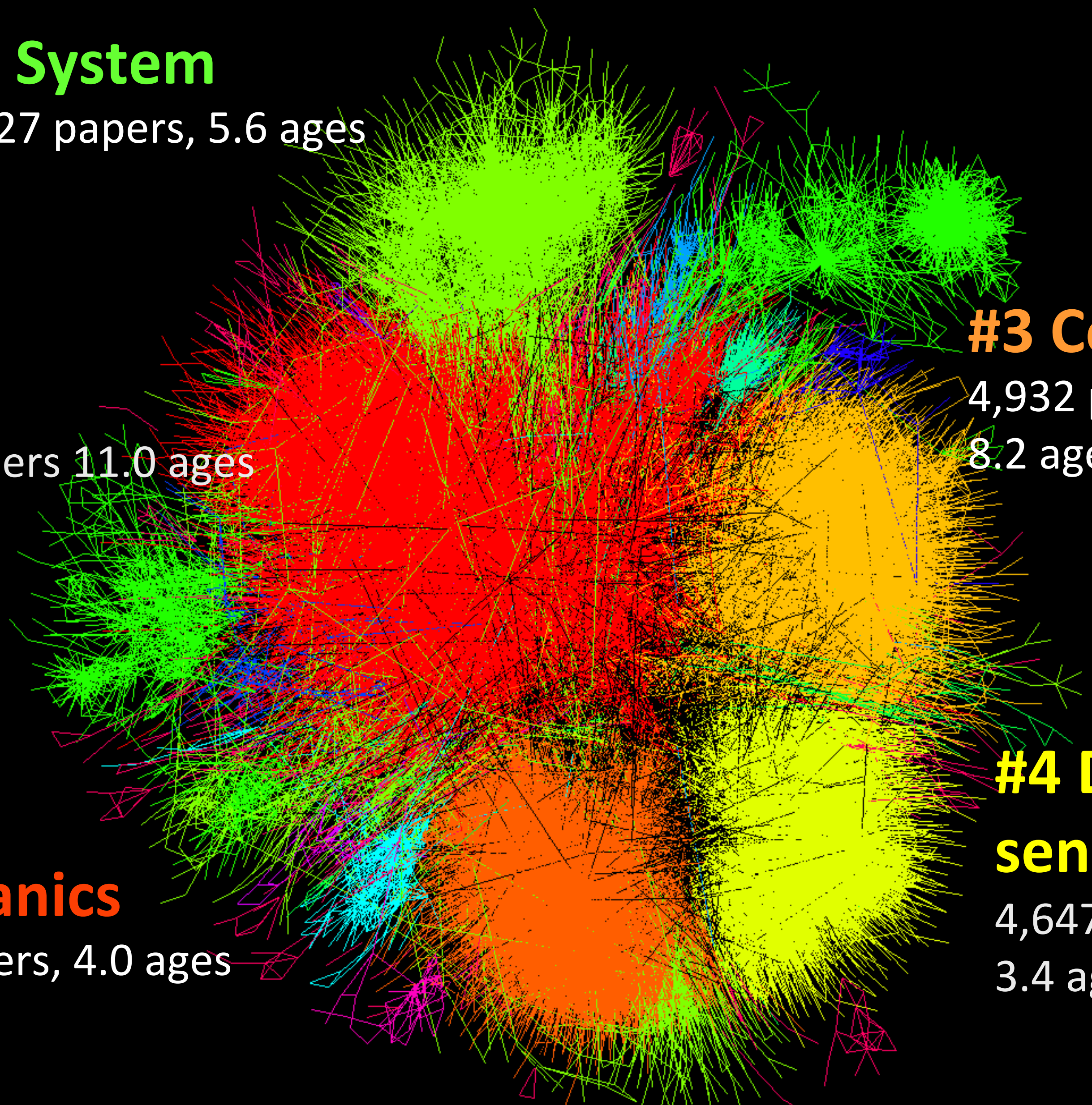

# Network

# Heat Map



# Academic Landscape of Solar Cell Research (1959-2009)




Age = 2009-(average publication year)

# Identifying Emerging Research Domains

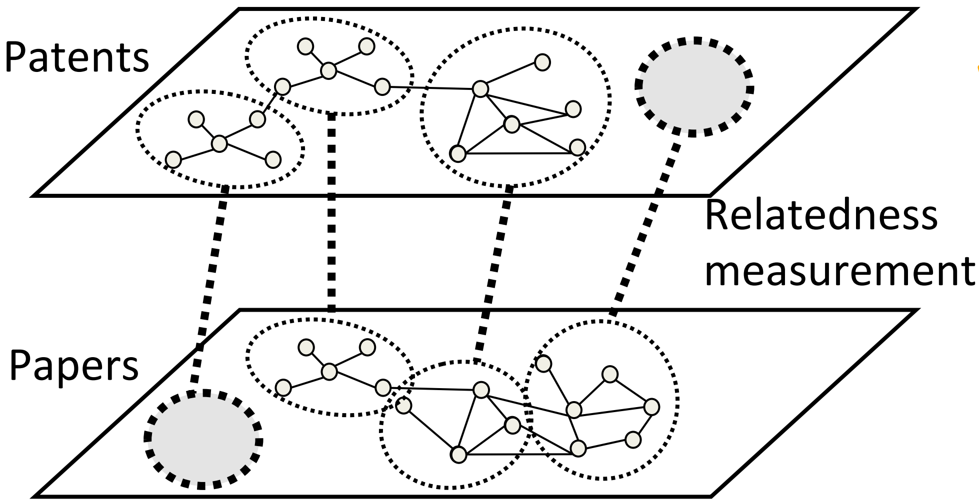
| 1st layer | 2nd layer | | | 3rd layer | | |
|---|---|---|---|---|---|---|
| Cluster name | Cluster name | Ages | Nodes | Cluster name | Ages | Nodes |
| Si | a-Si | 8.53 | 2905 | Degradation of a-Si | 15.33 | 785 |
| | | | | Microcrystalline | 4.93 | 705 |
| | | | | H dilution effect in a-Si:H | 7.27 | 573 |
| | | | | Textured ZnO | 5.57 | 432 |
| | Modeling | 21.78 | 2477 | Modeling of recombination | 20.37 | 747 |
| | | | | Compounds | 25.24 | 584 |
| | | | | Shottokky | 19.10 | 537 |
| | | | | Resistance | 23.20 | 359 |
| | High efficiency | 7.05 | 2196 | Tandem-type | 9.56 | 581 |
| | | | | Band structure | 5.82 | 478 |
| | c-SI | 6.13 | 2151 | Metal-induced crystallization | 6.63 | 481 |
| | | | | Surface passivation | 5.75 | 475 |
| | | | | Metal impurities | 7.61 | 409 |
| | | | | HIT | 3.71 | 231 |

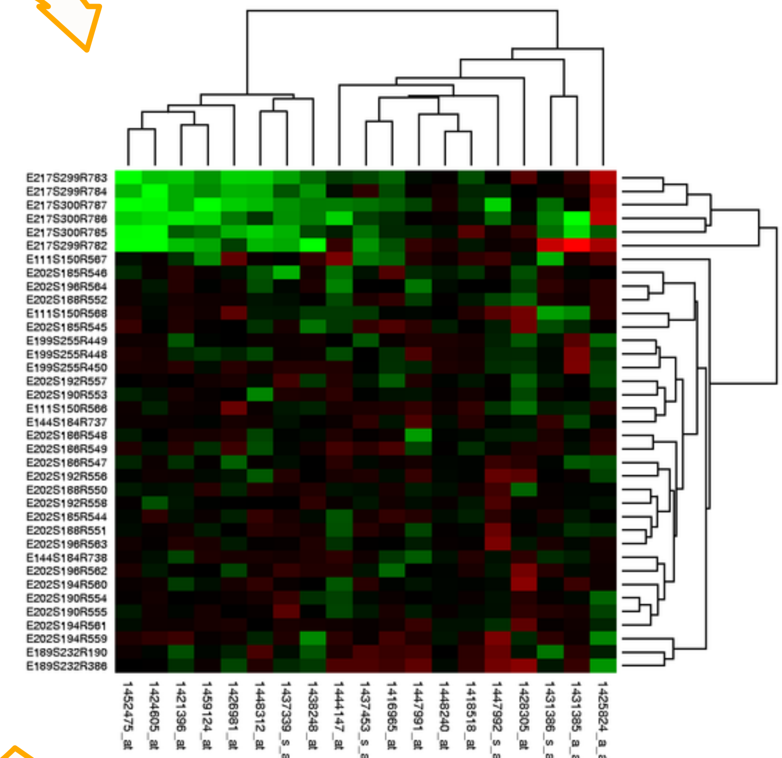
# Identifying Emerging Research Domains

| | | | | | | |
|---|---|---|---|---|---|---|
| Organics | Organics | 6.46 | 2023 | Double-hetero structure | 2.63 | 679 |
| | | | | phthalocyanine | 11.89 | 552 |
| | | | | Photodiode | 5.99 | 527 |
| | | | | Plastic solar cell | 3.00 | 521 |
| | New materials and processes | 2.31 | 1570 | Narrow bandgap | 2.05 | 517 |
| | | | | Liquid process | 1.62 | 423 |
| | Complexes with Nanoparticles | 2.49 | 1263 | Nanopartciels/polymer | 2.26 | 427 |
| | | | | Conjugated polymer | 2.15 | 402 |
| | | | | $TiO_2$ nanotube/polymer | 2.94 | 322 |
| | Complexes with Nanocarbons | 3.56 | 667 | nanotube/polymer | 2.33 | 177 |
| | | | | fullerene/olygomer | 3.95 | 168 |
| | | | | fullerene/ polyfiline | 3.44 | 106 |
| Dye-sensitized | Electrode | 2.97 | 1467 | Modeling | 4.23 | 520 |
| | | | | $TiO_2$ nanotube | 2.27 | 399 |
| | | | | Nano-structured ZnO | 2.08 | 387 |
| | Electrolyte | 3.28 | 1427 | Semi-solid electrolyte | 2.73 | 488 |
| | | | | Solid-electrolyte | 4.45 | 412 |
| | | | | Impedance measurement | 2.86 | 374 |
| | Photosensitizer | 3.69 | 1245 | Ru-based dyes | 4.56 | 4.88 |
| | | | | Molecular design | 2.00 | 327 |

# Extracting Candidates for Innovation

**Multi-layer analysis of paper and patents**

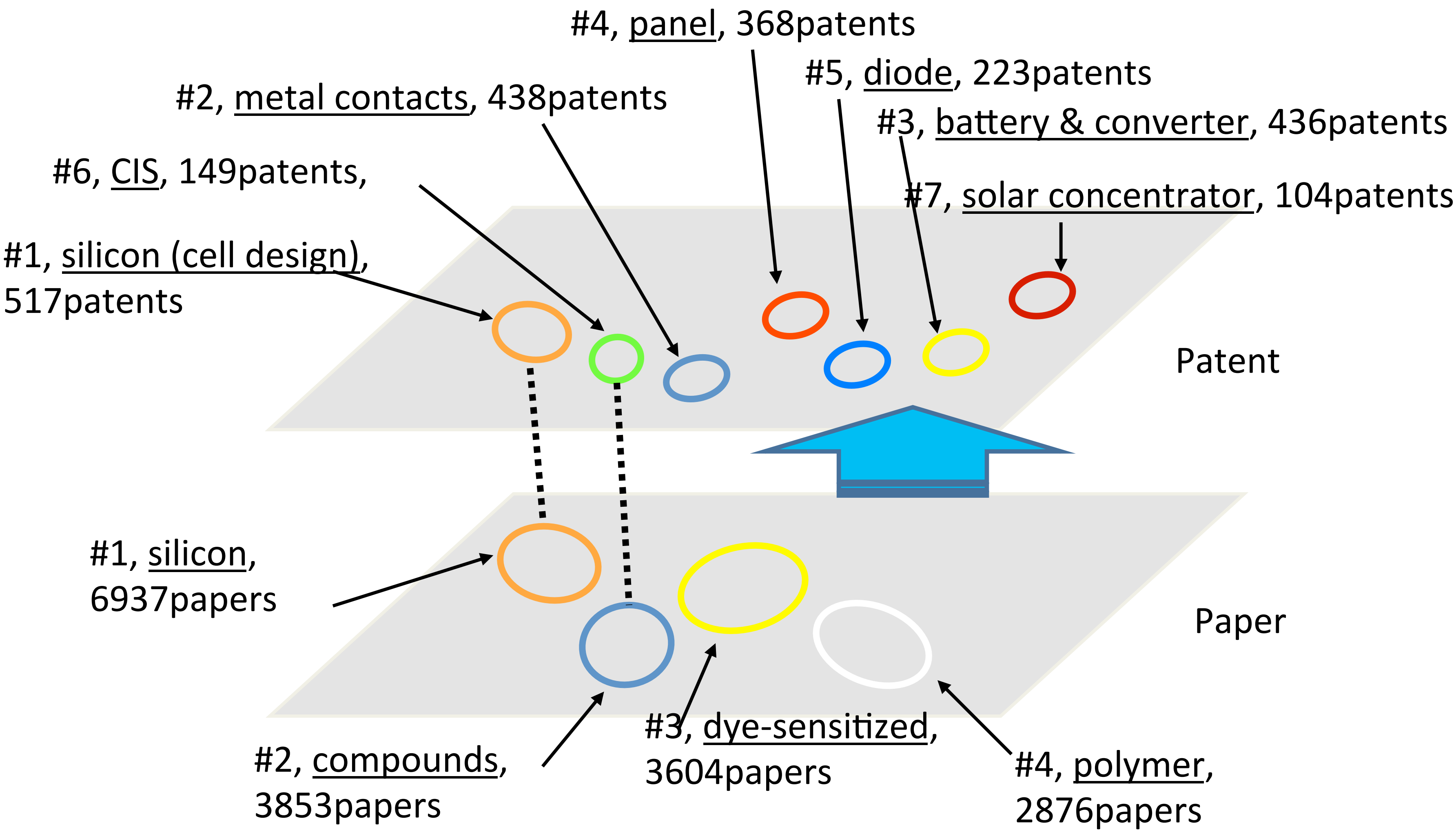


| | | Technology in Industry | |
|---|---|---|---|
| | | Exist | Not-exist |
| **Science** | Exist | A | B |
| | Not-exist | C | D |

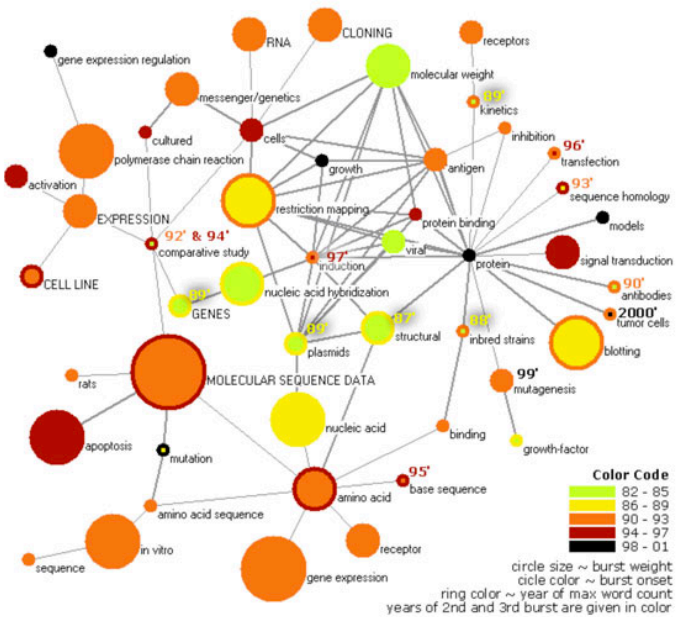
V. Ittipanuvat, K. Fujita, I. Sakata, and Y.Kajikawa "Finding Linkage between Technology and Social Issue: A Literature Based Discovery Approach," Journal of Engineering and Technology Management, 2013

# Science and Technology Linkage in Solar Cell Research

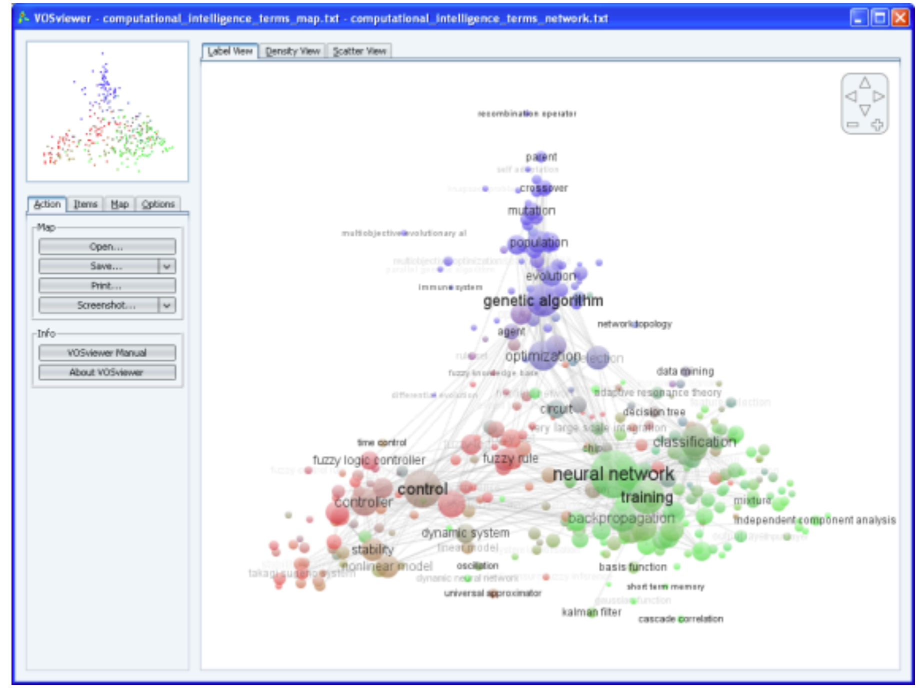


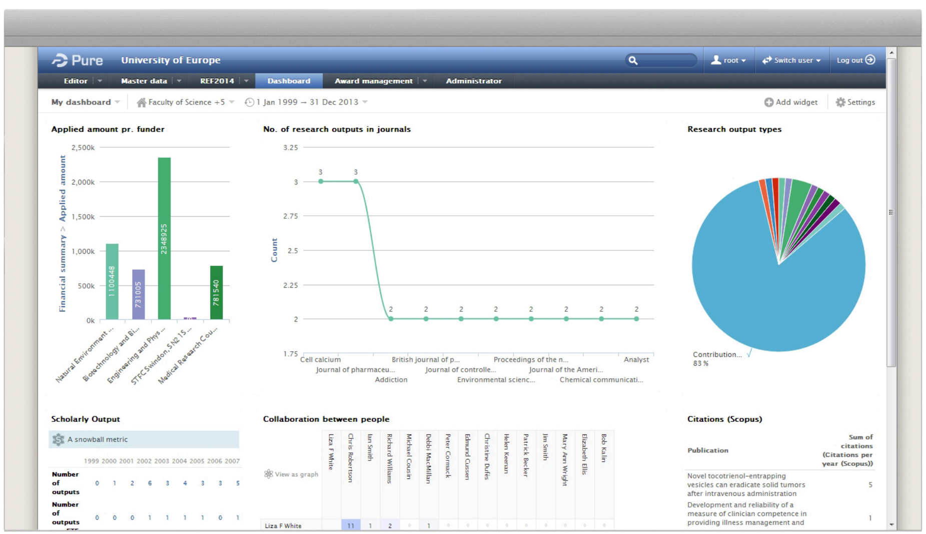

N. Shibata, Y. Kajikawa and I. Sakata. "Extracting the commercialization gap between science and technology", Technological Forecasting and Social Change 77(7) (2010) 1147-1155

# Related works

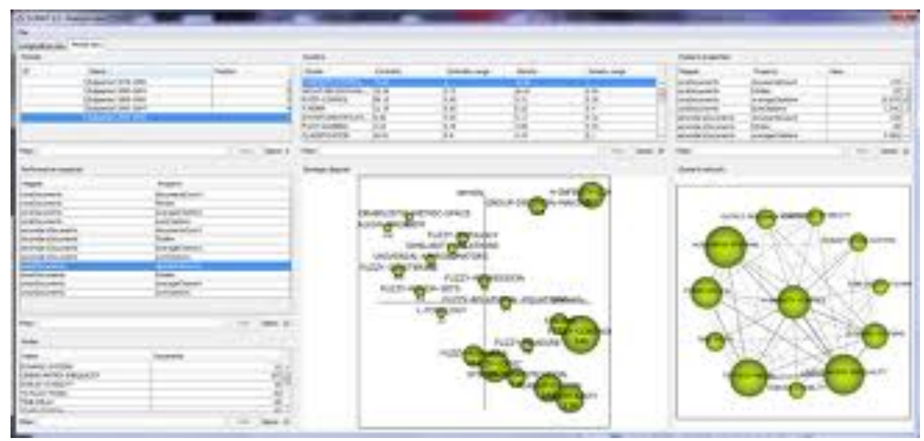



Mapping Topics and Topic Bursts in PNAS using Sci2




Science Mapping using VOSviewer



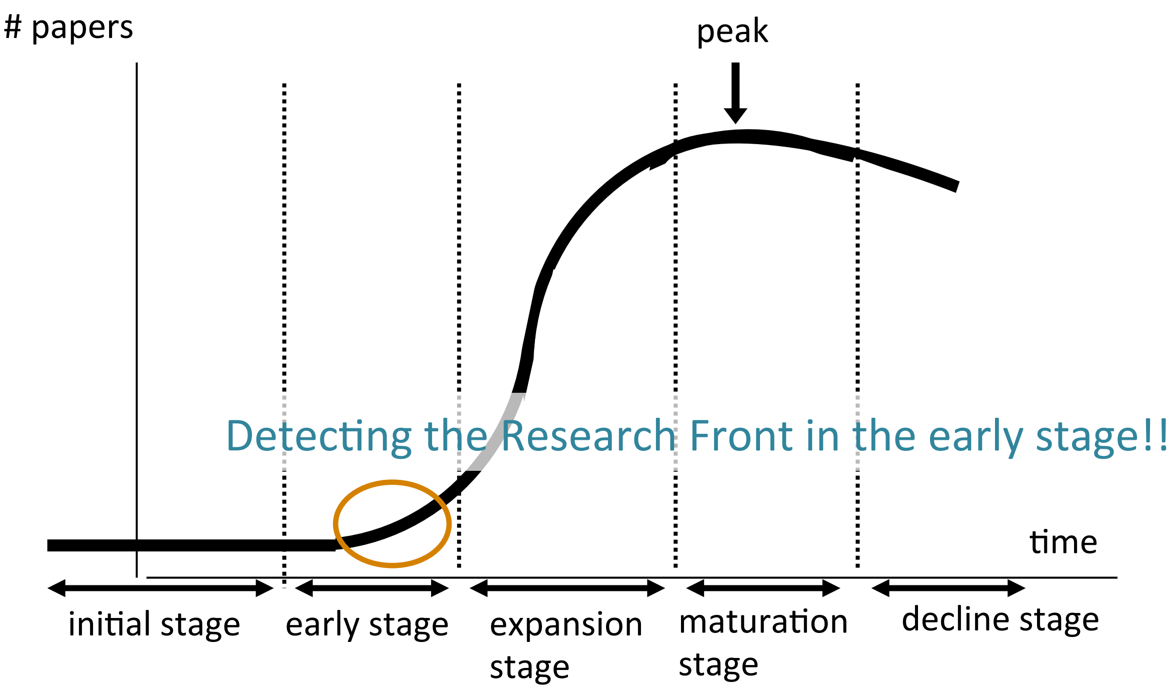
Research Performance Management using PURE

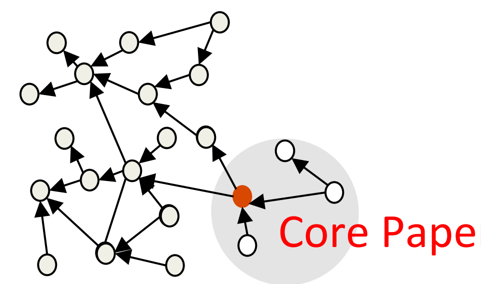
Science Mapping Analysis using SciMAT


# DETECTING THE RESEARCH FRONTS USING CITATION NETWORK ANALYSIS

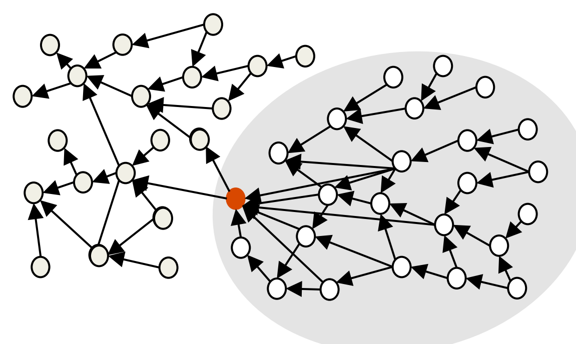
# Emerging research domains

- Gaining rapidly growing interests
- Its technology is not matured at the moment and therefore has limitations in industrial applications
- Its technology potentially has highly economic and social impacts in the near future




early stage



maturation stage

# Performance of Each method in Detecting Domains

**visibility, speed, topological and textual relevance of the cluster with core paper**

- Visibility (Cluster Size): $|N_i \in C_x| / |N|$

  ($|N|$:# of nodes, $|N_i \in C_x|$: # of nodes in core paper cluster $C_x$)

- Speed (Average publication year in the cluster)

- Topological relevance (Cluster Density): $|E_i \in C_x| / {}_{|N|}C_2$

  $|E_i \in C_x|$ : # of edges; both nodes are in the core paper cluster $C_x$

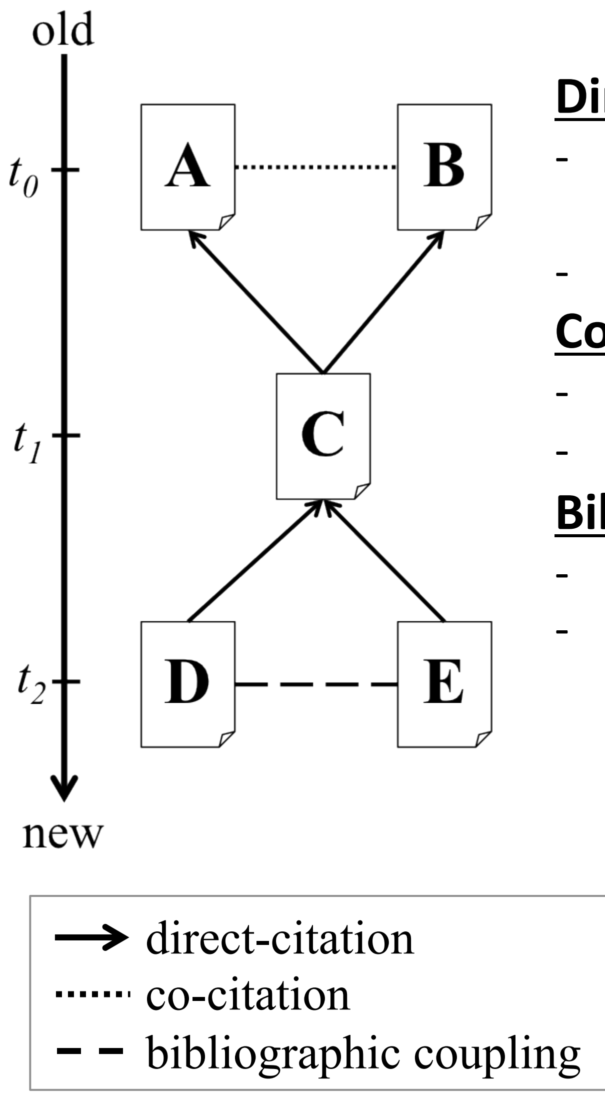
- Textual relevance (Keyword similarity):

$$\sum_{N_i \in C_x, N_j \in C_x (i \neq j)} Sim(N_i, N_j) / \sum_{C_i \in C} Sim(C_x, C_i)$$

(Paper Keyword Similarity in the cluster)

/ (Keyword Similarity between clusters and the core paper cluster)

# Type of Citations




**Direct citation**

- Edge between two documents when *paper C* cites *paper A* directly
- An earlier paper is cited by a new paper

**Co-citation**

- Edge between two documents cited by the same paper(s)
- Considering the number of citations

**Bibliographic coupling**

- Edge between two documents citing the same paper(s)
- Considering the number of citations

| | **Direct vs Co-citation vs Bibliographic** |
|---|---|
| Nodes | Direct > Bibliographic > Co-citation |
| Edges | Bibliographic > Co-citation > Direct |
| Year | Direct = Bibliographic > Co-citation |

# Weighted Citation Graph

* Jaccard similarity is defined by P. Jaccard 1912

(i) Frequency of citations: $w(E_{ij}) = |E_{ij}|$

*Considering the number of citations*

(ii) Difference of publication years:

$w(E_{ij}) = -|y_i - y_j|/10 + 2$ if $|y_i - y_j| > 10$, $w(E_{ij}) = 1$

*Differences between the publication years of paper are small => High*

(iii) Reference Similarity: $w(E_{ij}) = \text{Jaccard}(C_i, C_j) + 1$

*Similar reference list => High*

(iv) Keyword Similarity: $w(E_{ij}) = \text{Jaccard}(K_i, K_j) + 1$

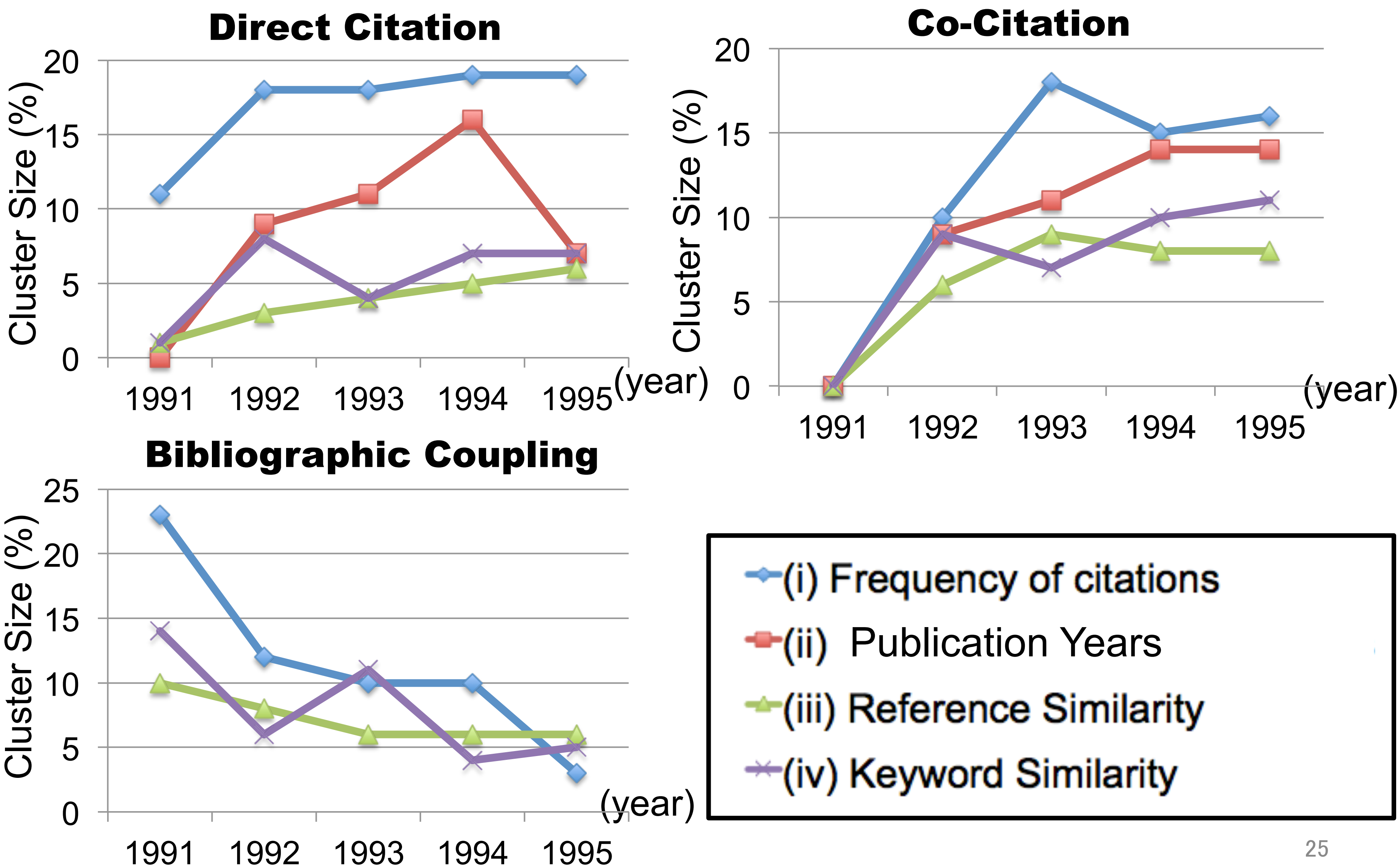
*Similar Keywords of papers => High*

- Graph: $G = (N, E, w)$, Node Set: $N=\{N_1,\ldots,N_i,\ldots,N_{|N|}\}$, Edge Set = $E=\{\ldots, E_{ij}, \ldots\}$
- $E_{ij}$: Edges between Node *i* and Node *j* ($|E_{ij}|$ :Number of citations between Node *i* and Node *j*
- Attributes of $N_i$: $y_i$: publication year $C_i$: reference set,
  $K_i$: Keyword (Author Keyword, Characteristic Keyword in Title and Abstract)

Katsuhide Fujita, Yuya Kajikawa, Junichiro Mori and Ichiro Sakata "Detecting research fronts using different types of weighted citation networks," Journal of Engineering and Technology Management, 2013 .

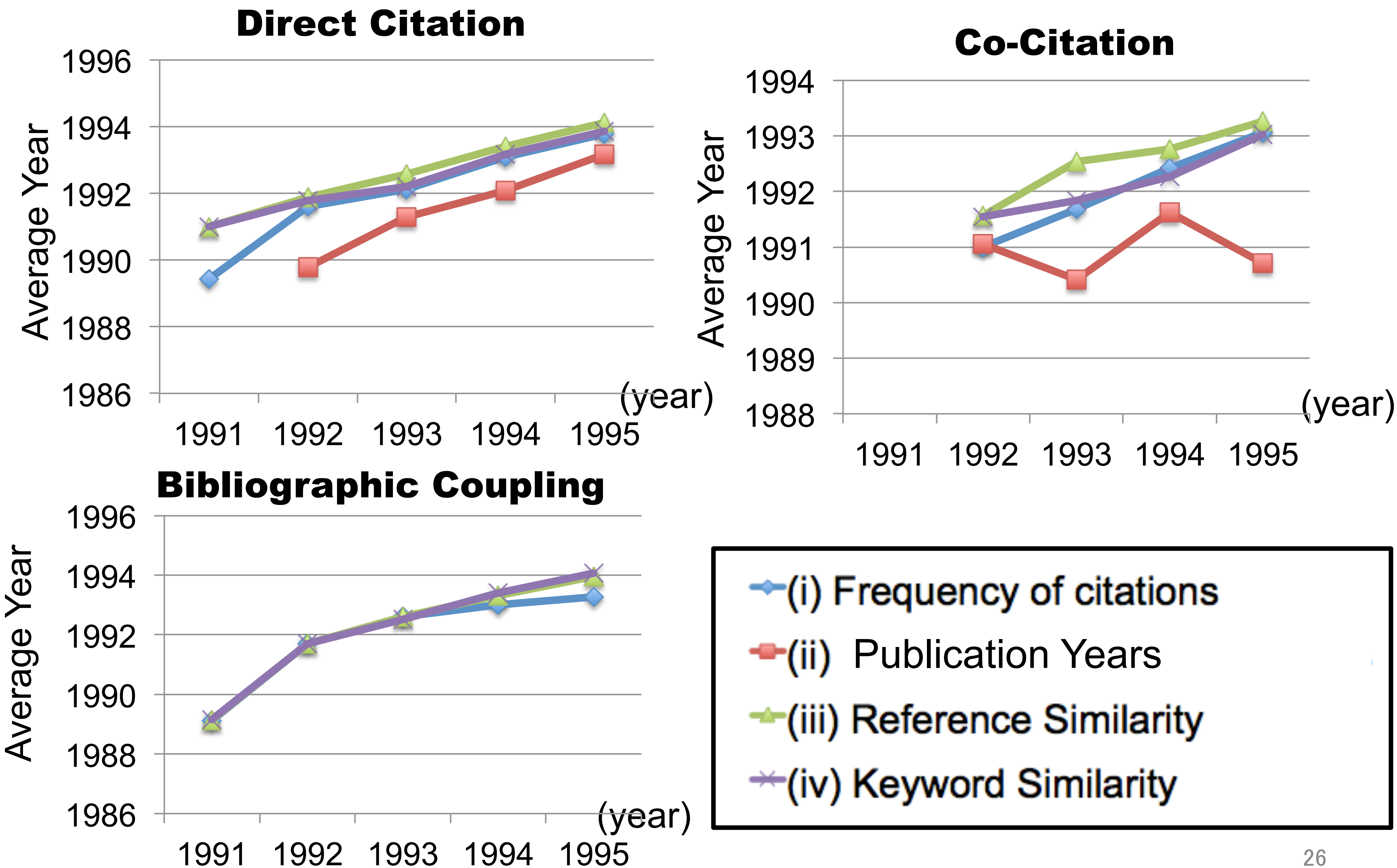
# Visibility (Cluster Size)

(B) IIJIMA, S, 1991, NATURE, V354, P56



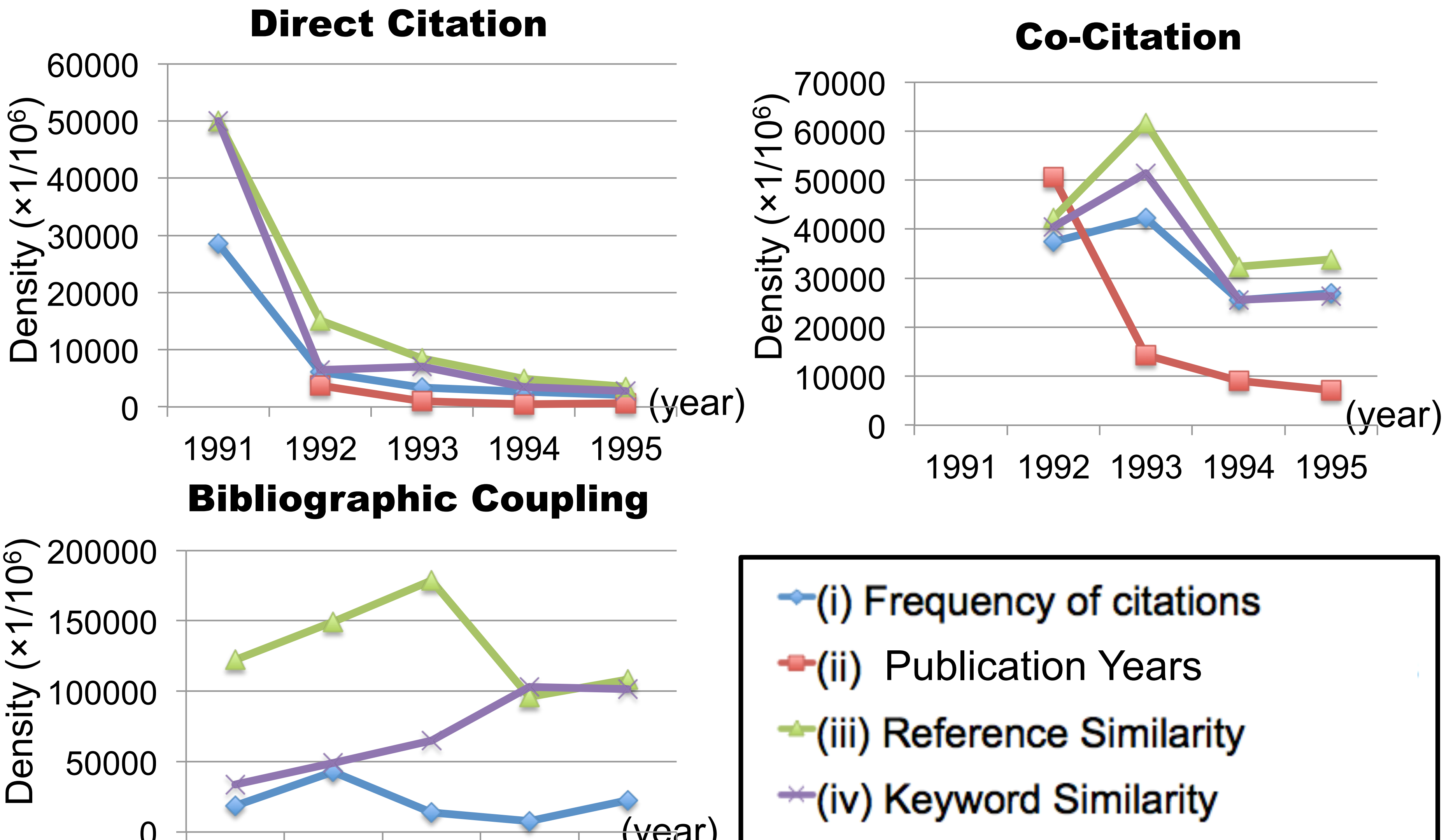
# Speed (Average publication year)

(B) IIJIMA, S, 1991, NATURE, V354, P56



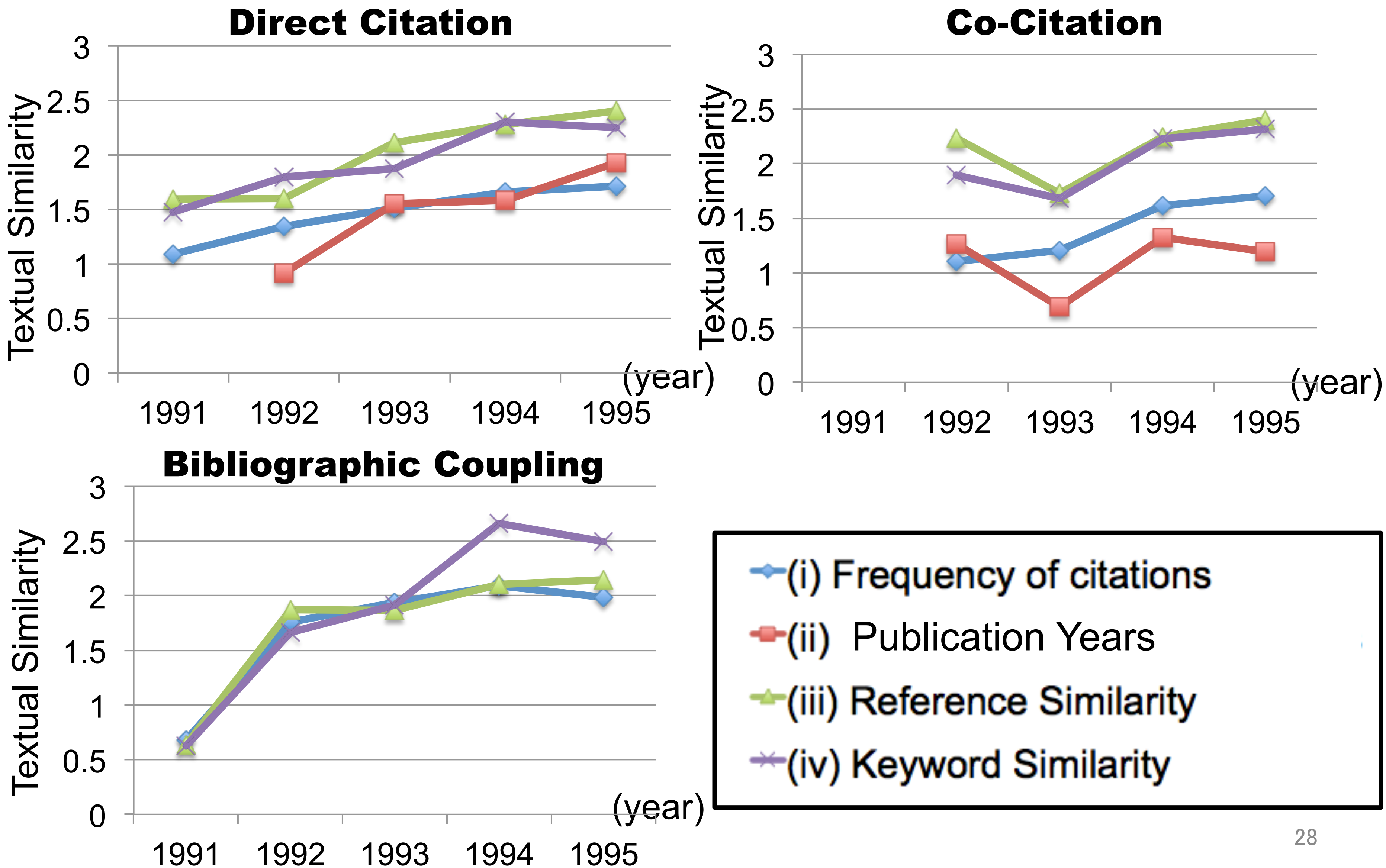
# Topological relevance (Cluster Density)

(B) IIJIMA, S, 1991, NATURE, V354, P56



# Textual Similarity

(B) IIJIMA, S, 1991, NATURE, V354, P56



# Discussion

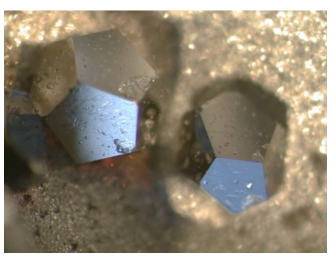
- "(i) Frequency of citation" is **higher performance** in all metrics when the types of citations are co-citation and bibliographic coupling
  - The frequency of citation is effective to find the emerging fronts
- "(ii) Difference of publication year" shows the **worst** results regarding as the average publication year
  - It divides the too small clusters
  - The functions based on the Difference of publication year should be improved
- "(iii) Reference Similarity" and "(iv) Keyword Similarity" are effective to divide **the accurate clusters**
  - The weights based on the references and keywords help dividing the accurate clusters
  - Reference information helps dividing the topological accurate clusters
  - Keywords of papers help dividing the textual accurate clusters

# Early Detection of Emerging Research Fronts

**Quasi-crystal (the 2011 Nobel Prize in Chemistry)**

Photo: U. Montan

**Dan Shechtman**

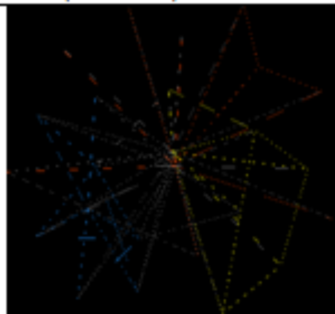
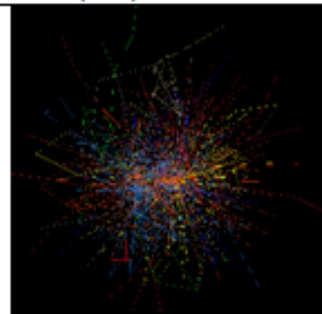
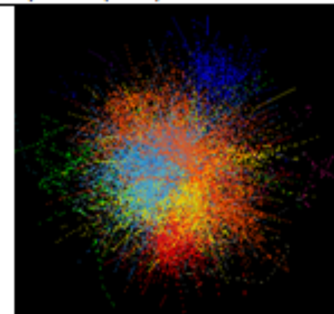
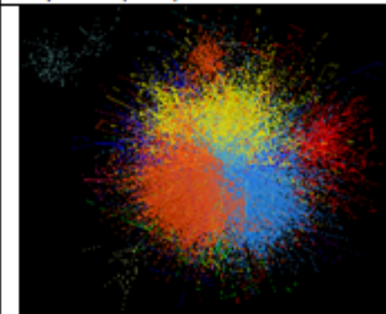


quasi-crystal
(Tsai Lab., Tohoku Univ.)

- Published Year: 1984
- Cited Count: 3,402
- History of quasi-crystal's discovery
  - Quasi-crystal is discovered in 1982.
  - His discovery was not understood by his boss., and he lost his job.
  - In 1983, He got a job of Israel Institute of Technology.
  - In 1984, he and his colleagues submitted a paper into *Journal of Applied Physics*, but it was rejected by editor.
  - In 1984, they submitted it into *Physical Review Letters*, and it was accepted.

This emerging research was not acknowledged at its initial stage.

TABLE II
The Growth of the Citation Network (N/F = Node / Facet, E/N = Edge / Node)

| Year | 1985 | 1990 | 1995 | 2000 |
|---|---|---|---|---|
| Facet | 102 | 449 | 2,127 | 4,168 |
| Node | 25 (N/F: 24.5%) | 285 (63.5%) | 1,497 (70.4%) | 2,873 (68.9%) |
| Edge | 72 (E/N: 2.88) | 840 (2.95) | 8,247 (5.51) | 18,877 (6.57) |
| Map |  |  |  |  |

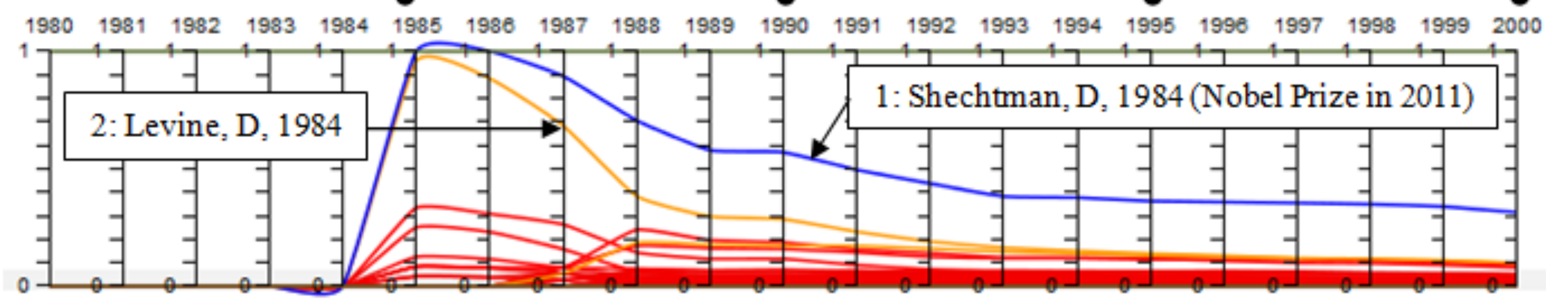



**Fig. 2. Time Transition about in-Degree Centralities of 311 Papers Published in 1981-1990**

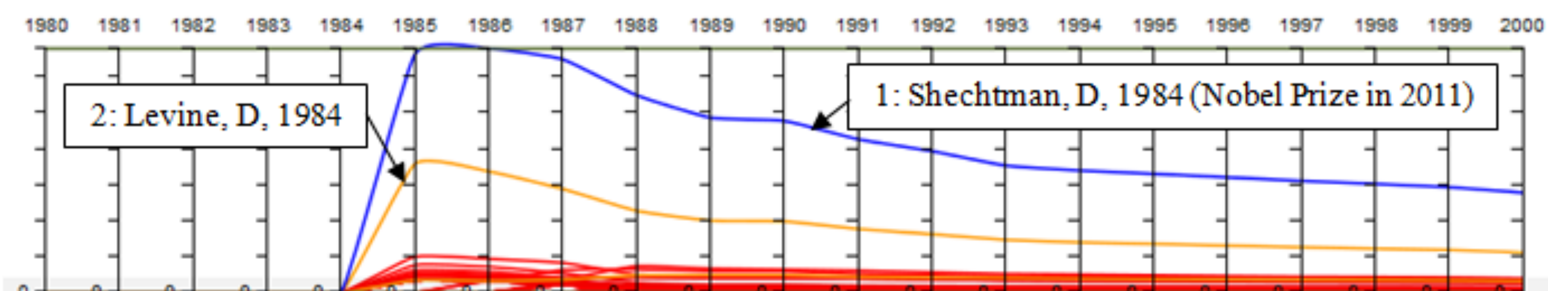



**Fig. 3. Time Transition about PageRank of 311 Papers Published in 1981-1990**

Iwami, S., Mori, J., Sakata, I. & Kajikawa, Y. Detection method of emerging leading papers using time transition. Scientometrics 101, 1515–1533 (2014).

# Early Detection of Emerging Research Fronts

*Aequorea victoria (Jellyfish)*
[Photo by Sierra Blakely]

GFPs are extracted

GFPs are inserted into other creatures.
[Credit: Mayo Clinic]

**Fluorescent Protein (the 2008 Nobel Prize in Chemistry)**

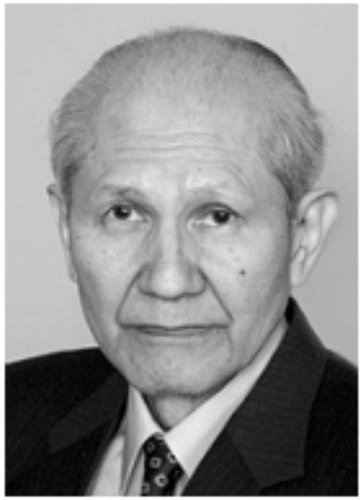


Photo: U. Montan

**Osamu Shimomura**

- Published Year: 1962
- Cited Count: 861
- He discovered GFP as a by-product.

Photo: U. Montan

**Martin Chalfie**

- Published Year: 1994
- Cited Count: 3,627
- He inserted GFPs into other creatures.

Photo: U. Montan

**Roger Y. Tsien**

- Published Year: 1998
- Cited Count: 2,761
- He developed various colored fluorescent

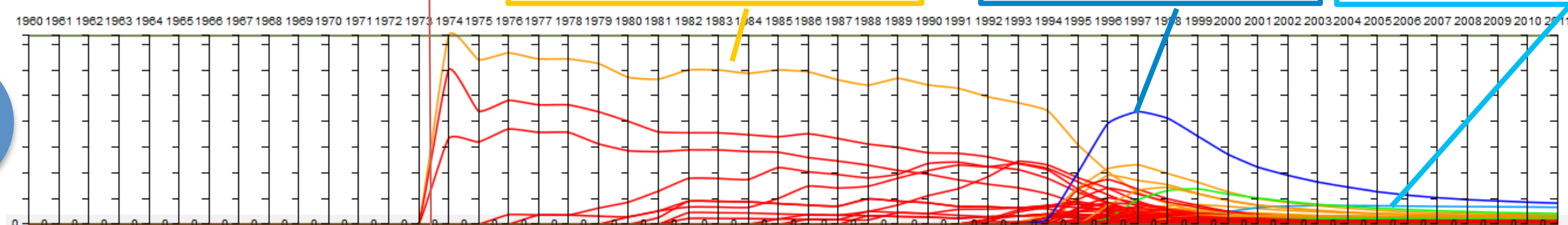
People do not notice this emerging research during 30 years.
The emerging research have less citations than others.

# Early Detection of Emerging Research Fronts

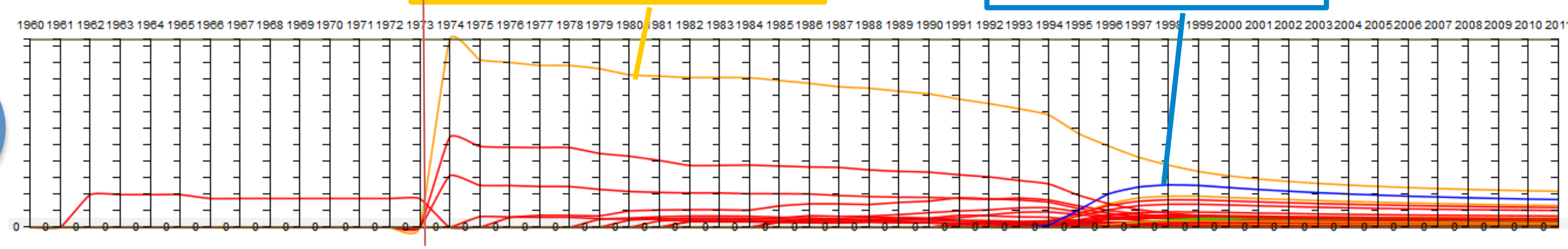
**Fluorescent Protein (the 2008 Nobel Prize in Chemistry)**

**Cited count within the dataset**(Reference)

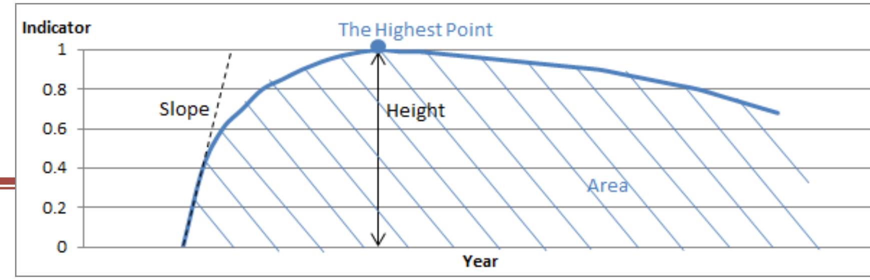

**in-Degree Centrality**




**PageRank**




Iwami, S., Mori, J., Sakata, I. & Kajikawa, Y. Detection method of emerging leading papers using time transition. Scientometrics 101, 1515–1533 (2014).




# gfp (1,967 papers)

Upper!

Shimomura, 1962

Chalfie, 1994

Tsien, 1998

## In-Degree Centrality

In-Degree Centrality

| Rank | 1st Author | PY | Height |
|---|---|---|---|
| 1 | SHIMOMURA, O | 1962 | 0.7333 |
| 2 | SHIMOMURA, O | 1965 | 0.6000 |
| 3 | CHALFIE, M | 1994 | 0.4380 |
| 4 | SHIMOMUR.O | 1969 | 0.3704 |
| 5 | INOUYE, S | 1985 | 0.2441 |
| 6 | BLINKS, JR | 1976 | 0.2414 |
| 7 | SHIMOMURA, O | 1975 | 0.2362 |
| 8 | PRASHER, DC | 1992 | 0.2309 |
| 9 | HEIM, R | 1994 | 0.1900 |
| 10 | WANG, SX | 1994 | 0.1754 |
| 21 | Tsien, RY | 1998 | 0.0724 |

| Rank | 1st Author | PY | Area |
|---|---|---|---|
| 1 | SHIMOMURA, O | 1962 | 15.2249 |
| 2 | SHIMOMURA, O | 1965 | 7.9612 |
| 3 | SHIMOMUR.O | 1969 | 5.7045 |
| 4 | CHALFIE, M | 1994 | 5.4929 |
| 5 | BLINKS, JR | 1976 | 5.2959 |
| 6 | SHIMOMURA, O | 1975 | 2.7550 |
| 7 | INOUYE, S | 1985 | 1.7498 |
| 8 | PRASHER, DC | 1992 | 1.7384 |
| 9 | WARD, WW | 1980 | 1.4662 |
| 10 | SHIMOMURA, O | 1979 | 1.4048 |
| 15 | Tsien, RY | 1998 | 0.8589 |

| Rank | 1st Author | PY | Slope |
|---|---|---|---|
| 1 | SHIMOMURA, O | 1962 | 0.7333 |
| 2 | SHIMOMURA, O | 1965 | 0.6000 |
| 3 | SHIMOMUR.O | 1969 | [illegible] |
| 4 | CHALFIE, M | 1994 | 0.1911 |
| 5 | WANG, SX | 1994 | 0.1500 |
| 6 | HEIM, R | 1994 | 0.1084 |
| 7 | PRASHER, DC | 1992 | 0.1011 |
| 8 | CUBITT, AB | 1995 | 0.0736 |
| 9 | Cormack, BP | 1996 | 0.0712 |
| 10 | CODY, CW | 1993 | 0.0701 |
| [illegible] | Tsien, RY | 1998 | 0.0259 |

| Rank | 1st Author | PY | SlopeAve |
|---|---|---|---|
| 1 | HEIM, R | 1994 | 49.6667 |
| 2 | Patterson, GH | 1997 | 25.5855 |
| 3 | SHEEN, J | 1995 | 12.5714 |
| 4 | DELAGRAVE, S | 1995 | 12.0667 |
| 5 | SHIMOMURA, O | 1962 | 11.5056 |
| 6 | Gerdes, HH | 1996 | 9.6925 |
| 7 | OGAWA, H | 1995 | 9.5714 |
| 8 | Siegel, MS | 1997 | 7.9167 |
| 9 | Cheng, LZ | 1996 | 6.8462 |
| 10 | AMSTERDAM, A | 1995 | 6.7143 |
| 307 | CHALFIE, M | 1994 | 0.1861 |
| 547 | Tsien, RY | 1998 | 0.0158 |

10th

## PageRank

PageRank

| Rank | 1st Author | PY | Height |
|---|---|---|---|
| 1 | SHIMOMURA, O | 1962 | 0.2276 |
| 2 | SHIMOMURA, O | 1965 | 0.1092 |
| 3 | SHIMOMUR.O | 1969 | 0.0625 |
| 4 | CHALFIE, M | 1994 | 0.0615 |
| 5 | STEINER, RF | 1962 | 0.0596 |
| 6 | PRASHER, DC | 1992 | 0.0577 |
| 7 | BLINKS, JR | 1976 | 0.0556 |
| 8 | SHIMOMURA, O | 1979 | 0.0555 |
| 9 | WARD, WW | 1980 | 0.0279 |
| 10 | SHIMOMURA, O | 1975 | 0.0257 |
| 27 | Tsien, RY | 1998 | 0.0049 |

| Rank | 1st Author | PY | Area |
|---|---|---|---|
| 1 | SHIMOMURA, O | 1962 | 4.7741 |
| 2 | SHIMOMURA, O | 1965 | 1.8754 |
| 3 | SHIMOMUR.O | 1969 | 1.0662 |
| 4 | CHALFIE, M | 1994 | 0.6874 |
| 5 | SHIMOMURA, O | 1979 | 0.6417 |
| 6 | BLINKS, JR | 1976 | 0.6144 |
| 7 | PRASHER, DC | 1992 | 0.5504 |
| 8 | WARD, WW | 1980 | 0.5258 |
| 9 | STEINER, RF | 1962 | 0.4571 |
| 10 | SHIMOMURA, O | 1975 | 0.5620 |
| 29 | Tsien, RY | 1998 | 0.0485 |

| Rank | 1st Author | PY | Slope |
|---|---|---|---|
| 1 | SHIMOMURA, O | 1962 | 0.2276 |
| 2 | SHIMOMURA, O | 1965 | 0.1092 |
| 3 | SHIMOMUR.O | 1969 | 0.0625 |
| 4 | STEINER, RF | 1962 | 0.0596 |
| 5 | CHALFIE, M | 1994 | 0.0197 |
| 6 | SHIMOMURA, O | 1975 | 0.0128 |
| 7 | PRASHER, DC | 1992 | 0.0127 |
| 8 | BLINKS, JR | 1976 | 0.0118 |
| 9 | SHIMOMURA, O | 1979 | 0.0097 |
| 10 | WARD, WW | 1980 | 0.0087 |
| 66 | Tsien, RY | 1998 | 0.0009 |

| Rank | 1st Author | PY | SlopeAve |
|---|---|---|---|
| 1 | SHIMOMURA, O | 1962 | 11.5056 |
| 2 | Siegel, MS | 1997 | 7.9167 |
| 3 | Stauber, RH | 1998 | 5.6564 |
| 4 | Oparka, KJ | 1997 | 5.5000 |
| 5 | Burke, NV | 1997 | 5.2727 |
| 6 | WARD, WW | 1982 | 4.6786 |
| 7 | OLSON, KR | 1995 | 4.5000 |
| 8 | BRINI, M | 1995 | 4.4000 |
| 9 | MONTERO, M | 1995 | 4.1429 |
| 10 | Klein, RL | 1998 | 4.0909 |
| 279 | CHALFIE, M | 1994 | 0.0155 |
| 599 | Tsien, RY | 1998 | 0.0004 |

10th

## Number of Citation

Number of Citation

| Rank | 1st Author | PY | Height |
|---|---|---|---|
| 1 | CHALFIE, M | 1994 | 2571 |
| 2 | Tsien, RY | 1998 | 1899 |
| 3 | Cormack, BP | 1996 | 1196 |
| 4 | PRASHER, DC | 1992 | 1028 |
| 5 | Ormo, M | 1996 | 949 |
| 6 | HEIM, R | 1994 | 820 |
| 7 | Shaner, NC | 2004 | 772 |
| 8 | Campbell, RE | 2002 | 757 |
| 9 | Miyawaki, A | 1997 | 718 |
| 10 | Matz, MV | 1999 | 715 |
| 17 | SHIMOMURA, O | 1962 | 469 |

| Rank | 1st Author | PY | Area |
|---|---|---|---|
| 1 | CHALFIE, M | 1994 | 22918 |
| 2 | Tsien, RY | 1998 | 12740 |
| 3 | Cormack, BP | 1996 | 10894 |
| 4 | PRASHER, DC | 1992 | 10116 |
| 5 | HEIM, R | 1994 | 7819 |
| 6 | Ormo, M | 1996 | 7590 |
| 7 | CUBITT, AB | 1995 | 7256 |
| 8 | Miyawaki, A | 1997 | 5591 |
| 9 | Yang, F | 1996 | 5569 |
| 10 | Crameri, A | 1996 | 4952 |
| 12 | SHIMOMURA, O | 1962 | 4547 |

| Rank | 1st Author | PY | Slope |
|---|---|---|---|
| 1 | CHALFIE, M | 1994 | 261 |
| 2 | Tsien, RY | 1998 | 165 |
| 3 | Shaner, NC | 2004 | 155 |
| 4 | Cormack, BP | 1996 | 151 |
| 5 | PRASHER, DC | 1992 | 124 |
| 6 | Campbell, RE | 2002 | 115 |
| 7 | Shaner, NC | 2005 | 94 |
| 8 | Nagai, T | 2002 | 90 |
| 9 | CUBITT, AB | 1995 | 89 |
| 10 | Ormo, M | 1996 | 85 |
| 16 | SHIMOMURA, O | 1962 | 58 |

| Rank | 1st Author | PY | SlopeAve |
|---|---|---|---|
| 1 | Tsien, RY | 1998 | 147 |
| 2 | CHALFIE, M | 1994 | 141 |
| 3 | Shaner, NC | 2004 | 125 |
| 4 | Campbell, RE | 2002 | 84 |
| 5 | Cormack, BP | 1996 | 81 |
| 6 | Shaner, NC | 2005 | 70 |
| 7 | Ormo, M | 1996 | 64 |
| 8 | Matz, MV | 1999 | 61 |
| 9 | PRASHER, DC | 1992 | 58 |
| 10 | Nagai, T | 2002 | 58 |
| 159 | SHIMOMURA, O | 1962 | 11 |

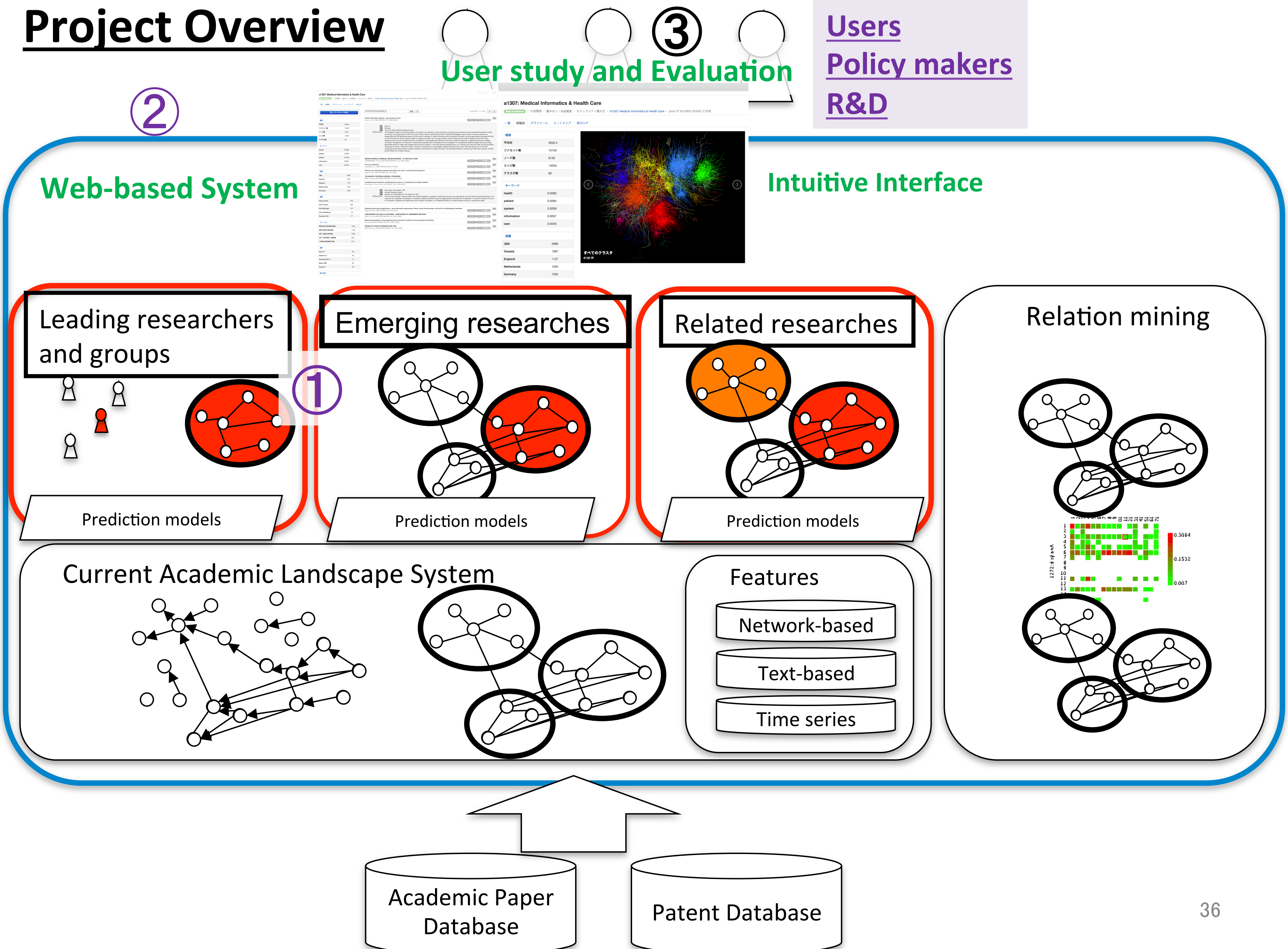
10th

Height Area Slope SlopeAve

# Academic and Technological Landscape System

- New Energy and Industrial Technology Development Organization (NEDO) funded project (FY2013-FY2017)
- Developing Scientific and Technological Landscape System
  - Detecting emerging researches
    - automatically detects rapidly growing technologies in the near future (emerging research)
  - Detecting related researches
    - Automatically detects complementary technologies to the emerging research (related research)
  - Detecting leading researchers and groups
    - Automatically detects researchers and their groups in the emerging research
- The system contributes to planning and executing a research and development strategy of both public and private sectors

# Project Overview



# Innovation system at the global frontiers

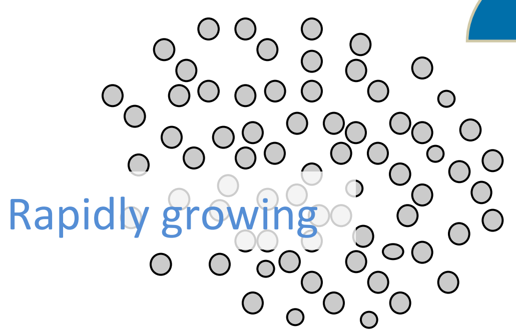
**Provide interdisciplinary knowledge base for policy discussion**

**Identify knowledge structure**
**Detect research fronts**

**Utilization and Integration of Knowledge**

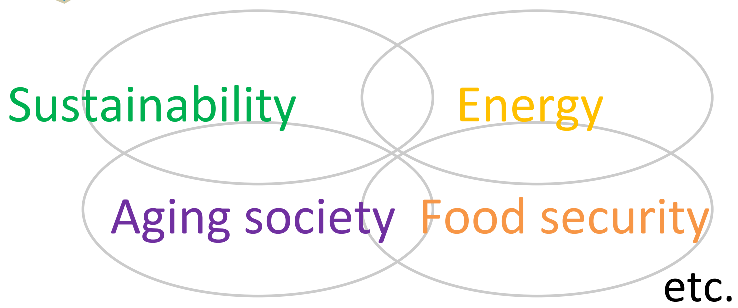
**Policy discussion:**
Feasibility of new social systems, new industry, collaboration etc.

**Accumulated Knowledge**




**Bridge science to challenges**

**Global Challenges**




**Survey on academic and industrial research front**

**Identification of To-Be model**

**Stimulating Social Innovation**

**Design new social systems, Improve institutional settings (regulation, standard・・・)**