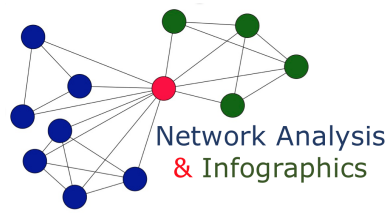
Innovation Networks

Dr Daniele Rotolo

SPRU (Science Policy Research Unit)
Business School
University of Sussex



Week 9

Learning Outcomes

	Learning outcome	Assessment mode
1	Explain the concept of network and list the main network indicators	ESS
2	Describe and apply the major techniques for the collection of network data and their statistical analysis	ESS, GPN + GWS
3	Identify the main characteristics of networks by means of network measures	ESS, GPN + GWS
4	Employ network analysis techniques to produce network data-based infographics	GPN + GWS

Note: ESS: Essay; GPN: Group Presentation; GWS: Group Written Submission

Overview

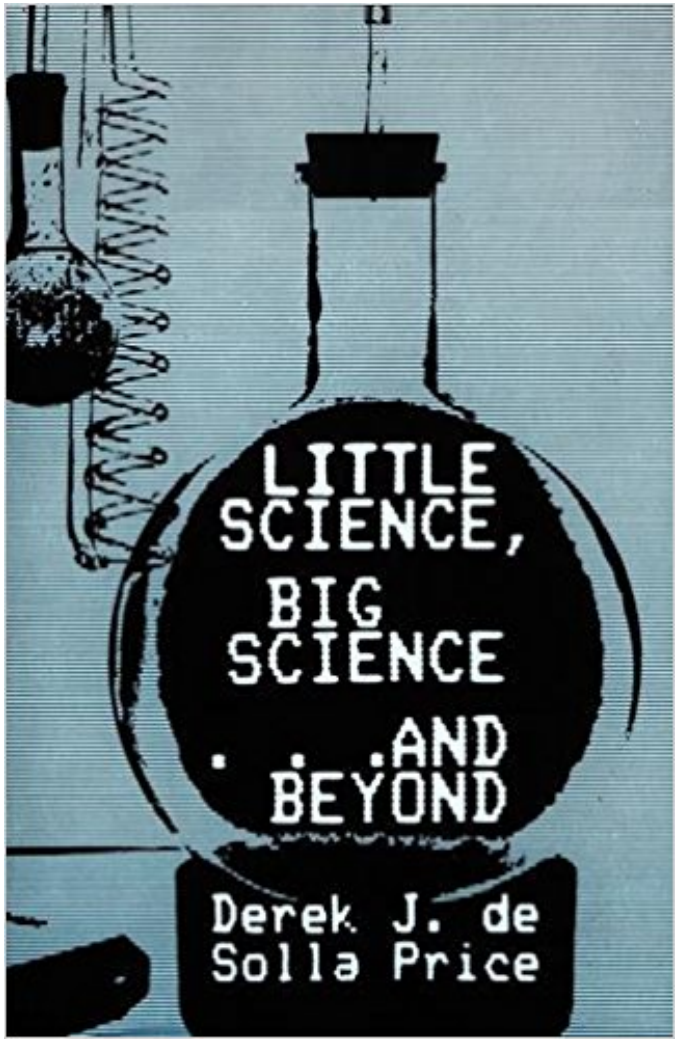
1. Bibliometrics/scientometrics
2. Mapping of collaboration
3. Mapping of cognitive connections

Bibliometrics/scientometrics

Bibliometrics/scientometrics

Definition

- Scientometrics is "the quantitative study of science, communication in science, and science policy" [Hess, 1997]
- Bibliometrics is "the measurement of patterns in written communication" [Broadus, 1987]
- *Bibliometrics in not restricted to scientific communication, while scientometrics is not restricted to bibliometric measures*
- Related sub-disciplines: informetrics, technometrics, research evaluation, altmetrics



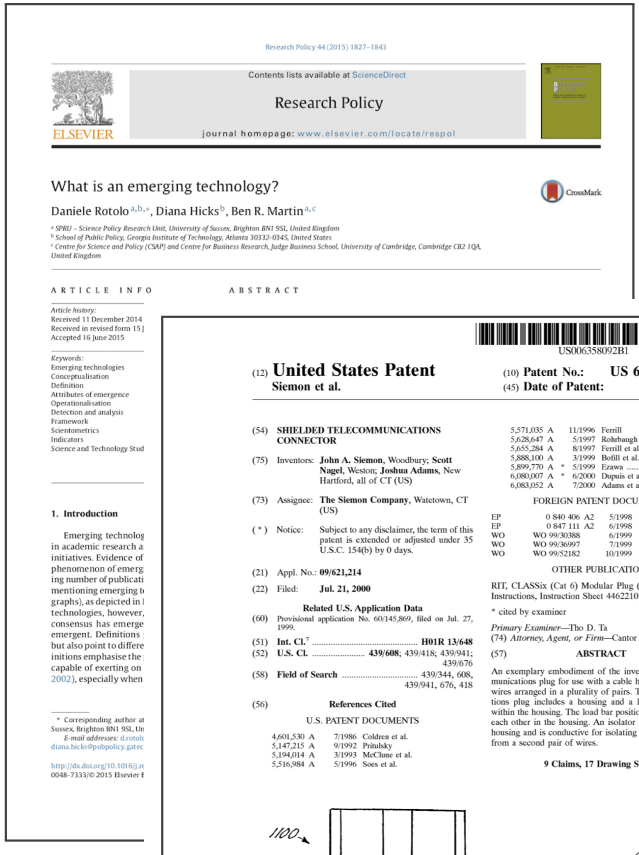
[de Solla Price, 1963]

Bibliometrics/scientometrics

Unit of analysis

Documents are the main source of data

- publications
- patents
- news articles
- ...



Research Policy 44 (2015) 1827–1843

Contents lists available at ScienceDirect

Research Policy

journal homepage: www.elsevier.com/locate/respol

What is an emerging technology?

Daniele Rotolo[a,b,*], Diana Hicks[b], Ben R. Martin[a,c]

[a] SPRU – Science Policy Research Unit, University of Sussex, Brighton BN1 9SL, United Kingdom
[b] School of Public Policy, Georgia Institute of Technology, Atlanta 30332-0345, United States
[c] Centre for Science and Policy (CSAP) and Centre for Business Research, Judge Business School, University of Cambridge, Cambridge CB2 1QA, United Kingdom

ARTICLE INFO

Article history:
Received 11 December 2014
Received in revised form 15 J
Accepted 16 June 2015

Keywords:
Emerging technologies
Conceptualisation
Definition
Attributes of emergence
Operationalisation
Detection and analysis
Framework
Scientometrics
Indicators
Science and Technology Stud

ABSTRACT

1. Introduction

Emerging technolog
in academic research a
initiatives. Evidence of
phenomenon of emerg
ing number of publicati
mentioning emerging t
graphs), as depicted in I
technologies, however,
consensus has emerge
emergent. Definitions
but also point to differe
initions emphasise the
capable of exerting on
2002), especially when

* Corresponding author at
Sussex, Brighton BN1 9SL, Un
E-mail addresses: d.rotolo
diana.hicks@pubpolicy.gatec

http://dx.doi.org/10.1016/j.re
0048-7333/© 2015 Elsevier

US006358092B1

(12) **United States Patent**
Siemon et al.

(10) **Patent No.: US 6,358,092 B1**
(45) **Date of Patent: Mar. 19, 2002**

(54) **SHIELDED TELECOMMUNICATIONS CONNECTOR**

(75) Inventors: **John A. Siemon**, Woodbury; **Scott Nagel**, Weston; **Joshua Adams**, New Hartford, all of CT (US)

(73) Assignee: **The Siemon Company**, Watetown, CT (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/621,214**

(22) Filed: **Jul. 21, 2000**

Related U.S. Application Data

(60) Provisional application No. 60/145,869, filed on Jul. 27, 1999.

(51) **Int. Cl.**[7] **H01R 13/648**

(52) **U.S. Cl.** **439/608**; 439/418; 439/941; 439/676

(58) **Field of Search** 439/344, 608, 439/941, 676, 418

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,601,530	A	7/1986	Coldren et al.
5,147,215	A	9/1992	Polnásky
5,194,014	A	3/1993	McClune et al.
5,516,984	A	5/1996	Soes et al.
5,571,035	A	11/1996	Ferrill
5,628,647	A	5/1997	Rohrbaugh et al.
5,655,284	A	8/1997	Ferrill et al.
5,888,100	A	3/1999	Boffil et al.
5,899,770	A *	5/1999	Ezawa 439/941
6,080,007	A *	6/2000	Dupuis et al. 439/941
6,083,052	A	7/2000	Adams et al.

FOREIGN PATENT DOCUMENTS

EP	0 840 406 A2	5/1998
EP	0 847 111 A2	6/1998
WO	WO 99/30388	6/1999
WO	WO 99/36997	7/1999
WO	WO 99/52182	10/1999

OTHER PUBLICATIONS

RIT, CLASSix (Cat 6) Modular Plug (RJ–45) Installation Instructions, Instruction Sheet 4462210, Mar. 2000.

* cited by examiner

Primary Examiner—Tho D. Ta
(74) *Attorney, Agent, or Firm*—Cantor Colburn LLP

(57) **ABSTRACT**

An exemplary embodiment of the invention is a telecommunications plug for use with a cable having a plurality of wires arranged in a plurality of pairs. The telecommunications plug includes a housing and a load bar positioned within the housing. The load bar positions wires relative to each other in the housing. An isolator is positioned in the housing and is conductive for isolating a first pair of wires from a second pair of wires.

9 Claims, 17 Drawing Sheets

Bibliometrics/scientometrics

Focus

- Measurement of impact (e.g. citation count, h-index, impact factor)
- Understanding of citation behavior (e.g. norms)
- Normalisation (e.g. comparison across research areas)
- Development of indicators to support decision making (e.g. funding)
- Mapping of science and technology

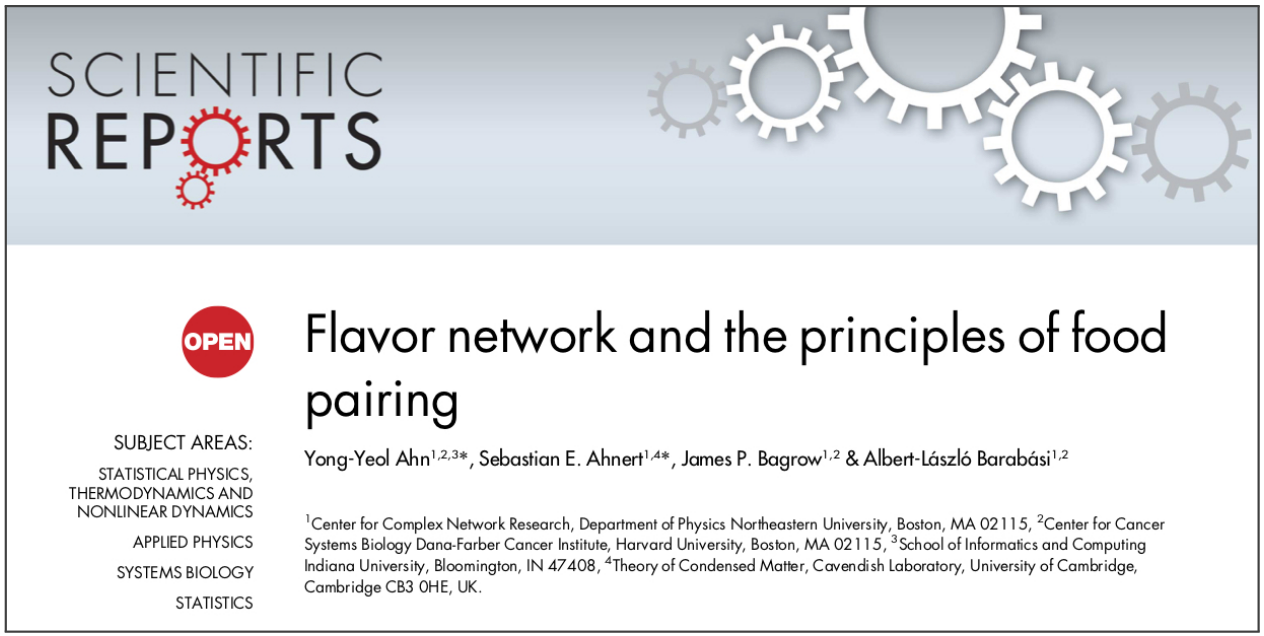
Network analysis has been extensively used in bibliometrics/scientometrics to map science and technology [Rotolo et al., 2015]

- Mapping of collaboration
- Mapping of cognitive connections

Mapping of collaboration

Mapping of collaboration

Publication data and co-authorship



SCIENTIFIC REPORTS

OPEN

SUBJECT AREAS:

STATISTICAL PHYSICS, THERMODYNAMICS AND NONLINEAR DYNAMICS

APPLIED PHYSICS

SYSTEMS BIOLOGY

STATISTICS

Flavor network and the principles of food pairing

Yong-Yeol Ahn[1,2,3*], Sebastian E. Ahnert[1,4*], James P. Bagrow[1,2] & Albert-László Barabási[1,2]

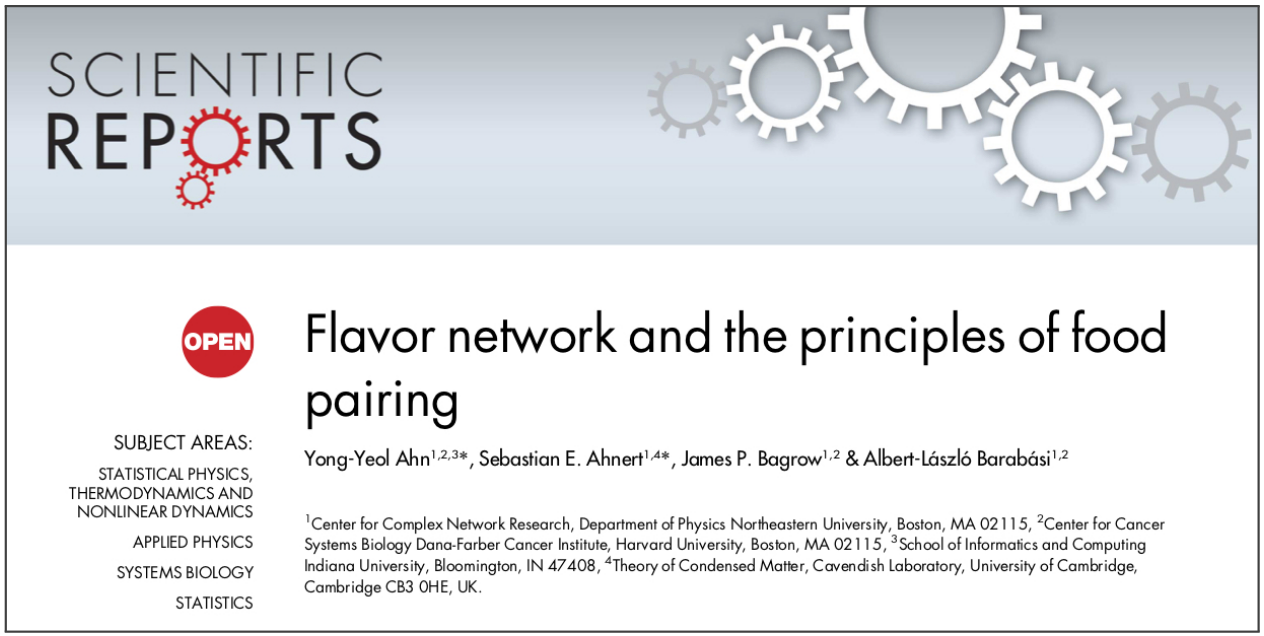
[1]Center for Complex Network Research, Department of Physics Northeastern University, Boston, MA 02115, [2]Center for Cancer Systems Biology Dana-Farber Cancer Institute, Harvard University, Boston, MA 02115, [3]School of Informatics and Computing Indiana University, Bloomington, IN 47408, [4]Theory of Condensed Matter, Cavendish Laboratory, University of Cambridge, Cambridge CB3 0HE, UK.

Source: [Ahn et al., 2011]

Mapping of collaboration

Publication data and co-authorship

- Authors
- Organisations
- Cities
- Countries



SCIENTIFIC REPORTS

OPEN

Flavor network and the principles of food pairing

SUBJECT AREAS:

STATISTICAL PHYSICS, THERMODYNAMICS AND NONLINEAR DYNAMICS

APPLIED PHYSICS

SYSTEMS BIOLOGY

STATISTICS

Yong-Yeol Ahn[1,2,3*], Sebastian E. Ahnert[1,4*], James P. Bagrow[1,2] & Albert-László Barabási[1,2]

[1]Center for Complex Network Research, Department of Physics Northeastern University, Boston, MA 02115, [2]Center for Cancer Systems Biology Dana-Farber Cancer Institute, Harvard University, Boston, MA 02115, [3]School of Informatics and Computing Indiana University, Bloomington, IN 47408, [4]Theory of Condensed Matter, Cavendish Laboratory, University of Cambridge, Cambridge CB3 0HE, UK.

Source: [Ahn et al., 2011]

Wide format

Publication	Authors
PUB1	AU1, AU2
PUB2	AU1, AU3
PUB3	AU3, AU4, AU5
...	...

Mapping of collaboration

Publication data and co-authorship

Wide format

Publication	Authors
PUB1	AU1, AU2
PUB2	AU1, AU3
PUB3	AU3, AU4, AU5
...	...

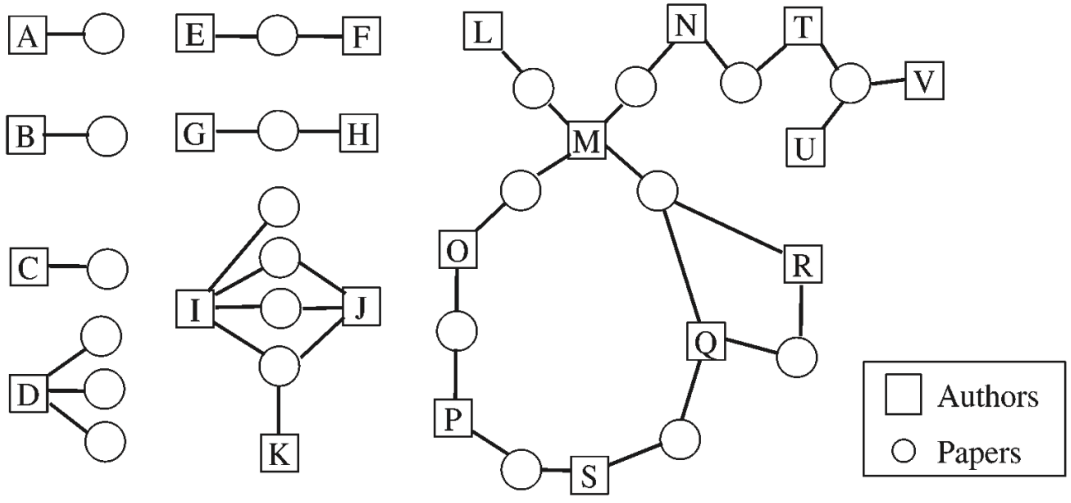
Long format

Publication	Author
PUB1	AU1
PUB1	AU2
PUB2	AU1
PUB2	AU3
PUB3	AU3
PUB3	AU4
PUB3	AU5
...	...

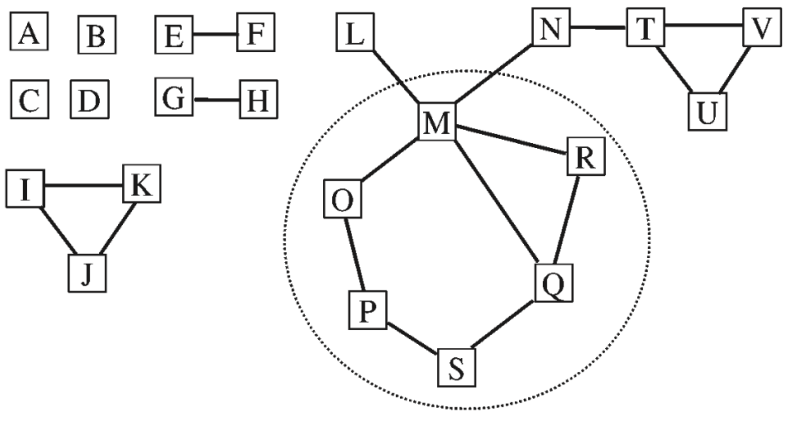
Mapping of collaboration

Publication data and co-authorship

a) Individual Publications



b) Collaboration Network



Degree Distribution

Degree	Freq
0	4
1	5
2	10
3	2
4	0
5	1

Source: Construction of the co-authorship network [Moody, 2004]

Mapping of collaboration
Publication data and co-authorship

Pioneering studies on co-authorship

- Increasing collaboration [de Solla Price, 1963]
- Structure and change of collaborative networks [Melin and Persson, 1996]
- Giant component, strength of collaboration, small-world [Newman, 2001]
- Preferential attachment [Albert and Barabasi, 2002]
- ...

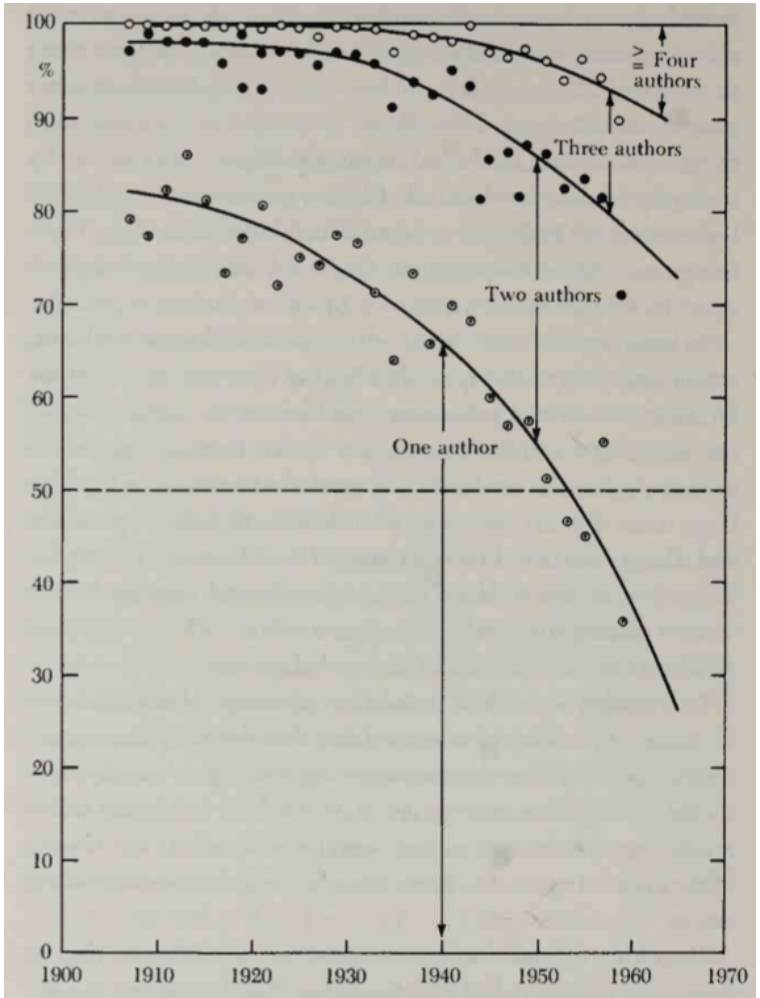


Figure 3.3. Incidence of Multiple Authorship as a Function of Date

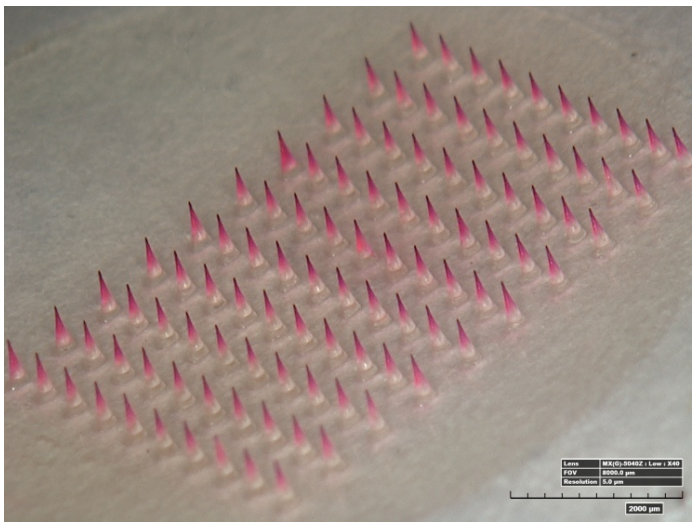
Data from *Chemical Abstracts*, 1910–1960, are here presented showing the percentages of papers having a single author and those with two, three, and four or more. It seems evident that there has been a steadily accelerating change since the beginning of the century.

Source: Invisible colleges [de Solla Price, 1963]

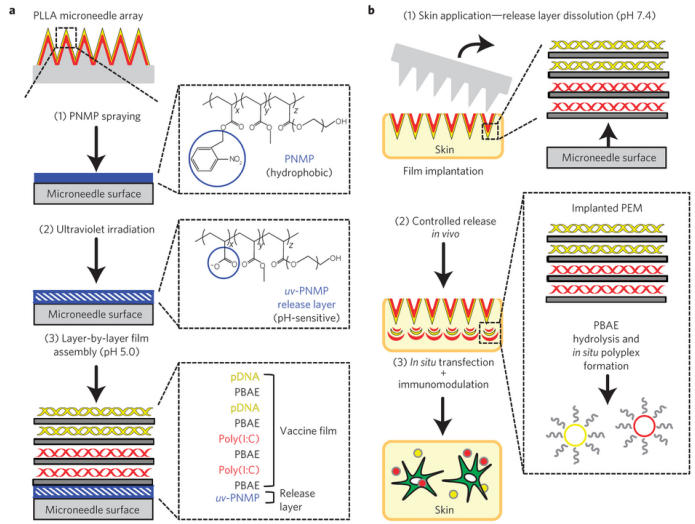
Mapping of collaboration

Publication data and co-authorship (example)

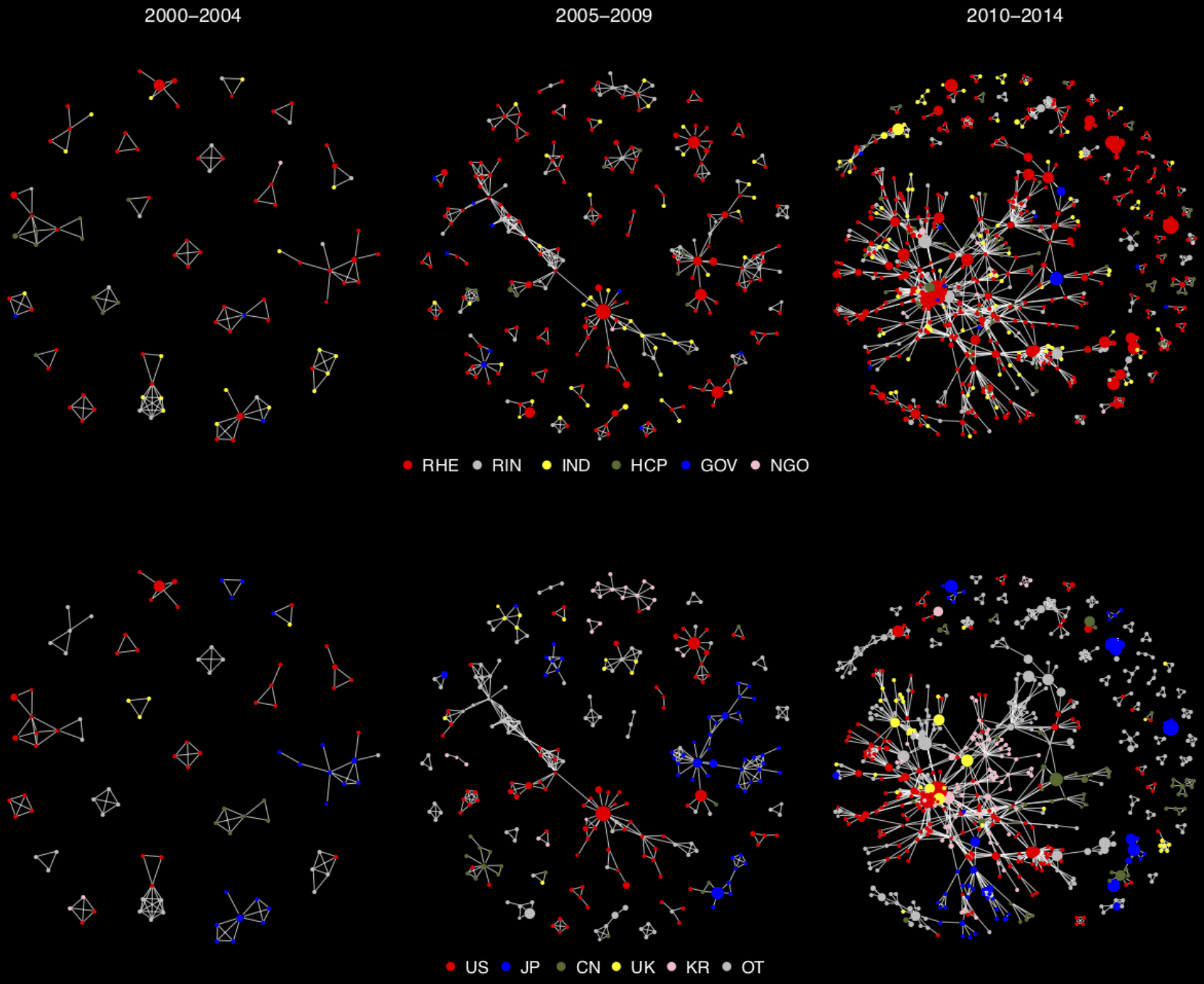
Microneedles: needles the size of which is on the *micrometer* length scale. Expected impact on vaccines, drug delivery, and reduction of biohazard waste



Source: `www.news.gatech.edu`



Source: [DeMuth et al., 2013]



Source: Co-authorship data in microneedles research (2000-2014)

Mapping of collaboration

Publication data and co-authorship

Publication	Authors
PUB1	AU1, AU2
PUB2	AU1, AU3
PUB3	AU3, AU4, AU5
...	...

When using co-authorship data to map collaboration networks,
do we make any assumption?

ELSEVIER

Research Policy 26 (1997) 1–18

research policy

What is research collaboration? [1]

J. Sylvan Katz, Ben R. Martin *

Science Policy and Research Evaluation Group, ESRC Centre for Science, Technology, Energy ad Environment Policy, Science Policy Research Unit, University of Sussex, Falmer, Brighton BN1 9RF, UK

Accepted 11 January 1995

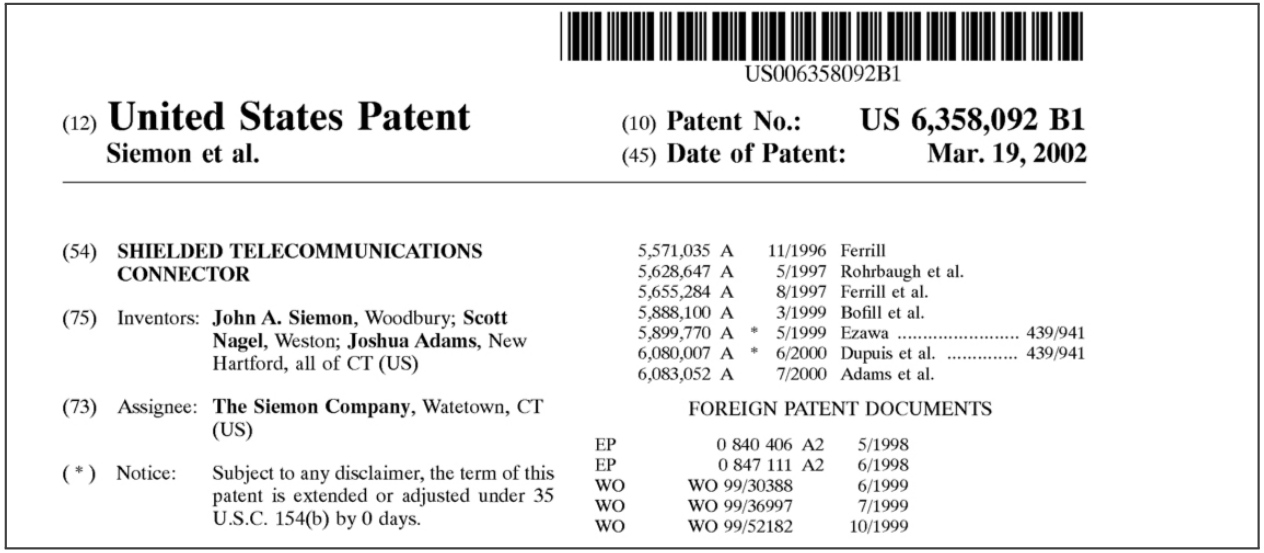
Abstract

Although there have been many previous studies of research collaboration, comparatively little attention has been given to the concept of 'collaboration' or to the adequacy of attempting to measure it through co-authorship. In this paper, we distinguish between collaboration at different levels and show that inter-institutional and international collaboration need not necessarily involve inter-individual collaboration. We also show that co-authorship is no more than a partial indicator of collaboration. Lastly, we argue for a more symmetrical approach in comparing the costs of collaboration with the undoubted benefits when considering policies towards research collaboration.

Source: [Katz and Martin, 1997]

Mapping of collaboration

Patent data and co-authorship



US006358092B1

(12) **United States Patent**
Siemon et al.

(10) **Patent No.: US 6,358,092 B1**
(45) **Date of Patent: Mar. 19, 2002**

(54) **SHIELDED TELECOMMUNICATIONS CONNECTOR**

(75) Inventors: **John A. Siemon**, Woodbury; **Scott Nagel**, Weston; **Joshua Adams**, New Hartford, all of CT (US)

(73) Assignee: **The Siemon Company**, Watetown, CT (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

5,571,035	A		11/1996	Ferrill
5,628,647	A		5/1997	Rohrbaugh et al.
5,655,284	A		8/1997	Ferrill et al.
5,888,100	A		3/1999	Bofill et al.
5,899,770	A	*	5/1999	Ezawa 439/941
6,080,007	A	*	6/2000	Dupuis et al. 439/941
6,083,052	A		7/2000	Adams et al.

FOREIGN PATENT DOCUMENTS

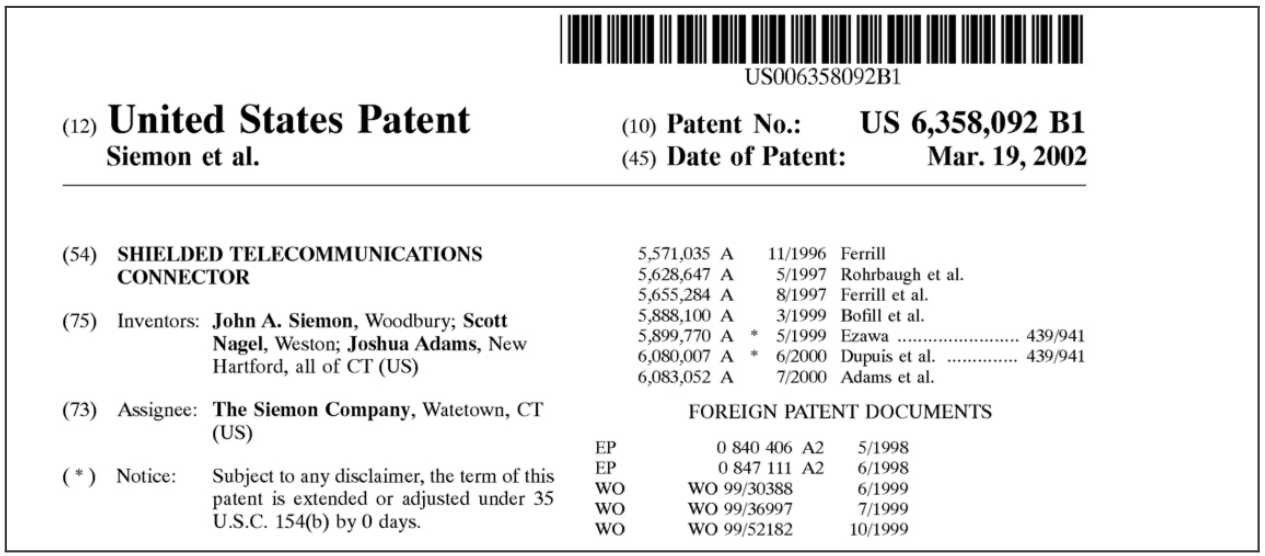
EP	0 840 406 A2	5/1998
EP	0 847 111 A2	6/1998
WO	WO 99/30388	6/1999
WO	WO 99/36997	7/1999
WO	WO 99/52182	10/1999

Source: Patent US 6,358,092

Mapping of collaboration

Patent data and co-authorship

- Inventors
- Organisations
- Cities
- Countries
- Assumptions



US006358092B1

(12) **United States Patent**
Siemon et al.

(10) **Patent No.: US 6,358,092 B1**
(45) **Date of Patent: Mar. 19, 2002**

(54) **SHIELDED TELECOMMUNICATIONS CONNECTOR**

(75) Inventors: **John A. Siemon**, Woodbury; **Scott Nagel**, Weston; **Joshua Adams**, New Hartford, all of CT (US)

(73) Assignee: **The Siemon Company**, Watetown, CT (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

5,571,035	A		11/1996	Ferrill
5,628,647	A		5/1997	Rohrbaugh et al.
5,655,284	A		8/1997	Ferrill et al.
5,888,100	A		3/1999	Bofill et al.
5,899,770	A	*	5/1999	Ezawa 439/941
6,080,007	A	*	6/2000	Dupuis et al. 439/941
6,083,052	A		7/2000	Adams et al.

FOREIGN PATENT DOCUMENTS

EP	0 840 406 A2	5/1998
EP	0 847 111 A2	6/1998
WO	WO 99/30388	6/1999
WO	WO 99/36997	7/1999
WO	WO 99/52182	10/1999

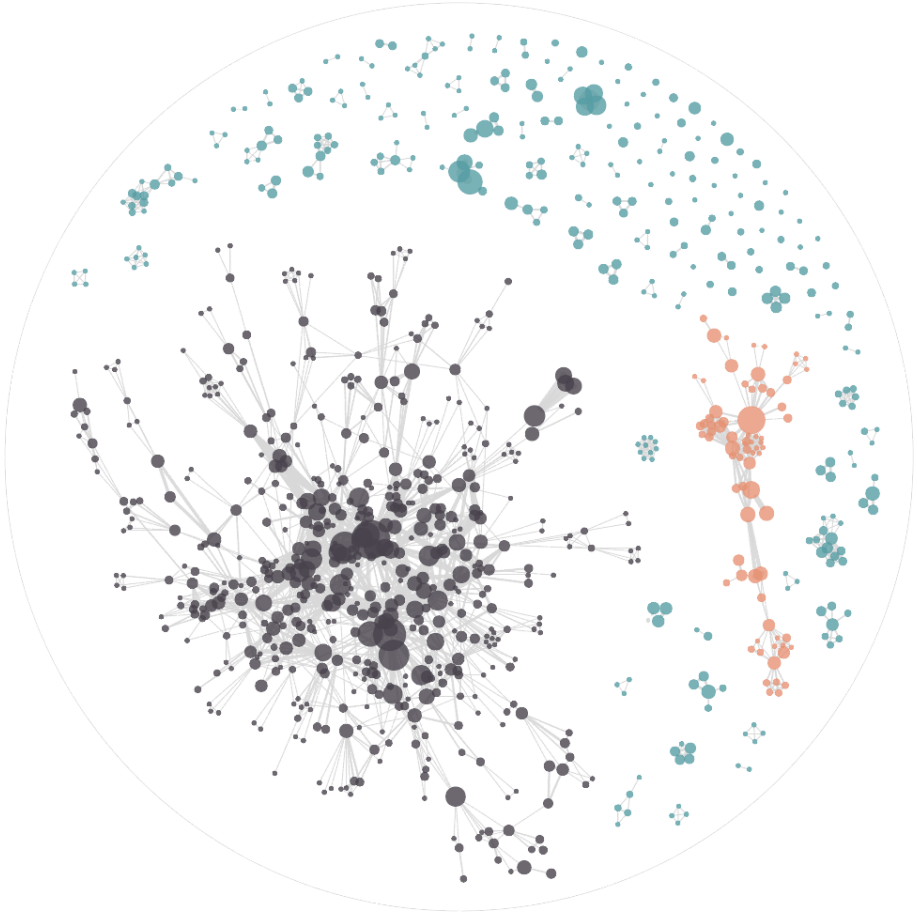
Source: Patent US 6,358,092

Mapping of collaboration

Patent data and co-authorship (example)

Tesla

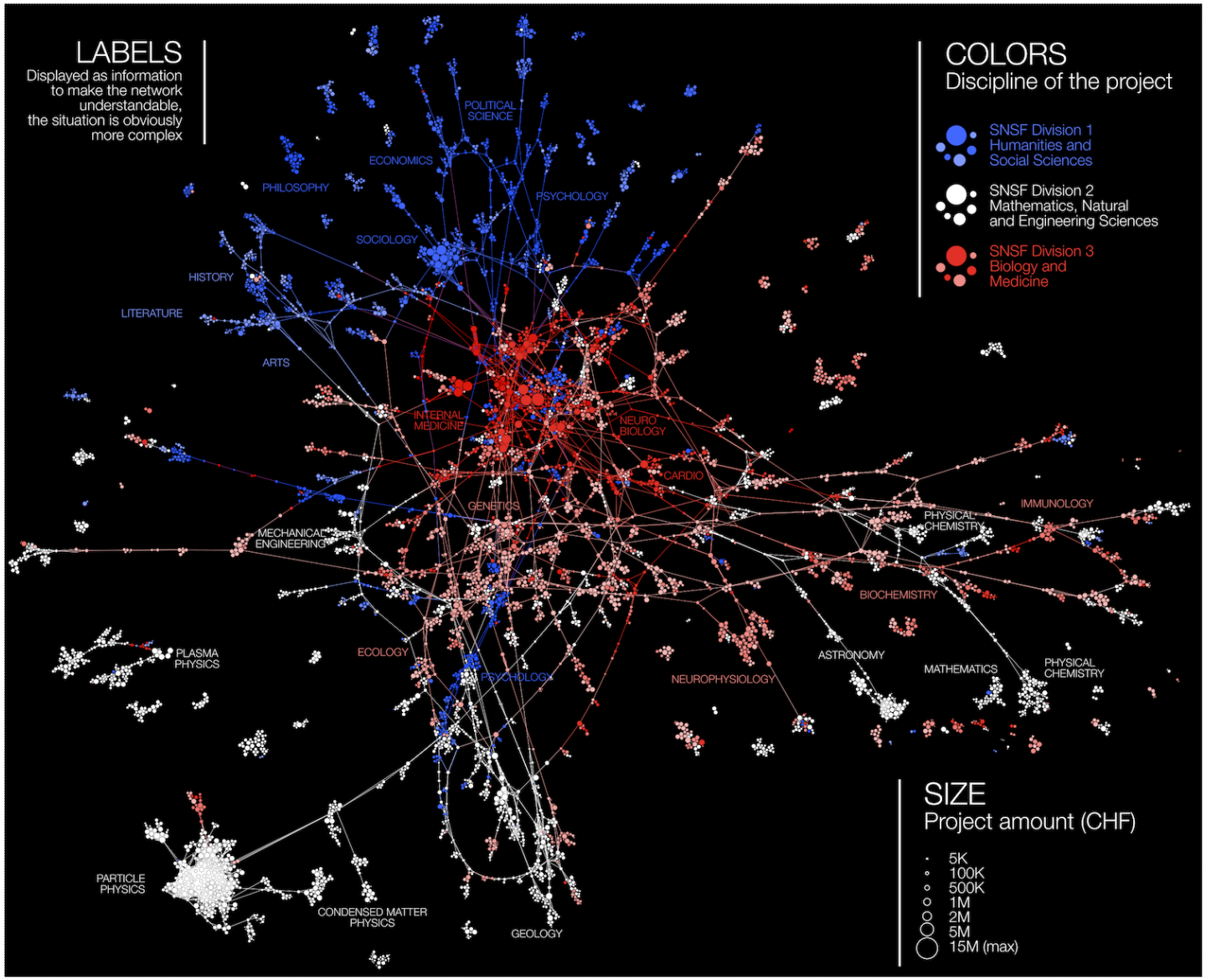
Facebook



Source: Co-patenting network [http://www.periscopic.com/news/exploring-innovation-signatures-in-patent-data]

Mapping of collaboration

Mapping collaborations (example)



Source: SNSF-funded projects (2006-2015;, link representing shares of researchers)
[www.martingrandjean.ch/complex-network-visualisation-interdisciplinarity/]

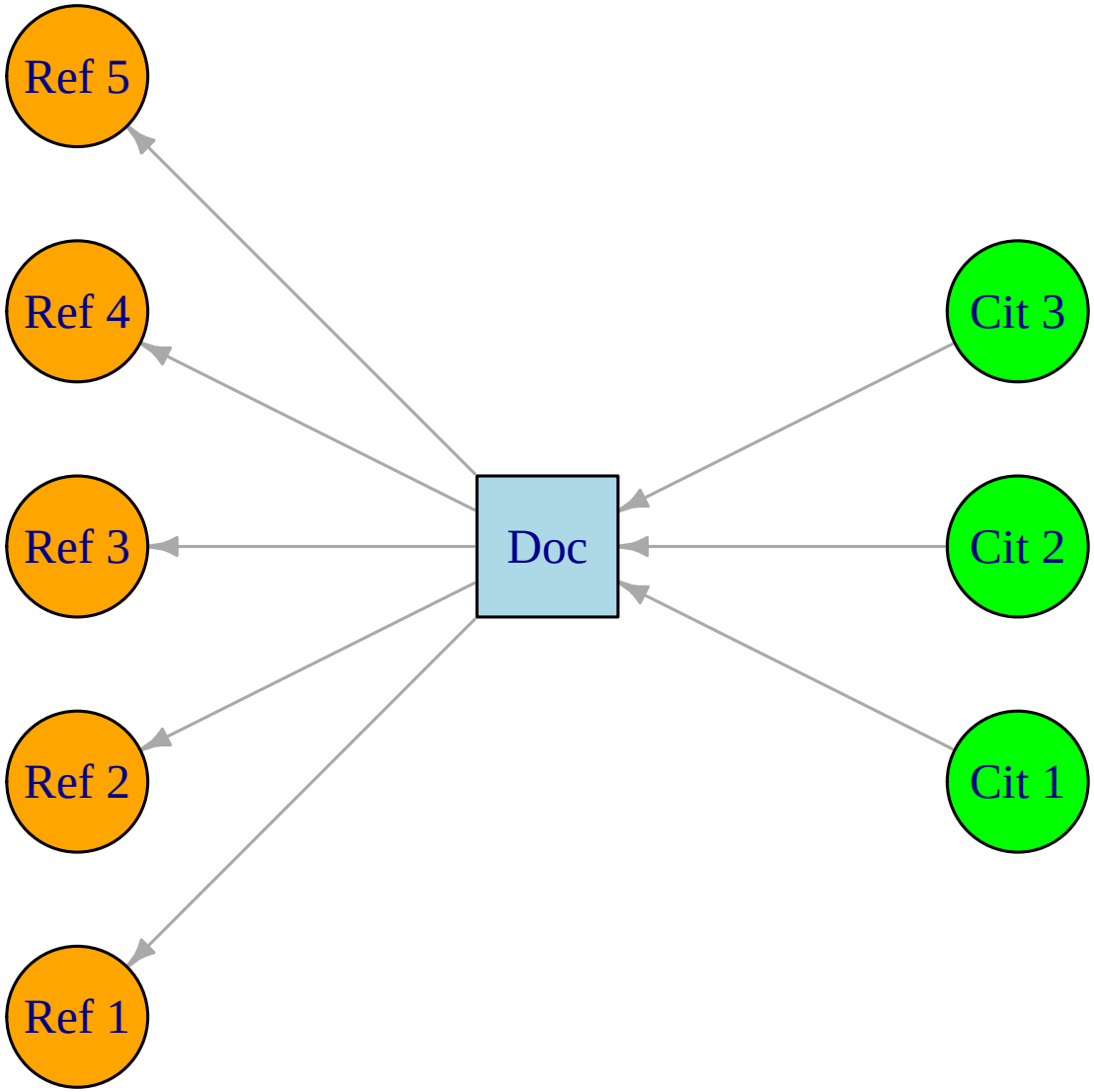
Mapping of cognitive connections

Main scientometrics/bibliometrics mapping techniques

- Citation analysis
  - Direct citation analysis [Garfield et al., 1964]
  - Co-citation analysis [Small, 1973]
  - Bibliographic coupling [Kessler, 1963]
- Co-word analysis [Callon et al., 1983]
- Overlay mapping [Rafols et al., 2010]

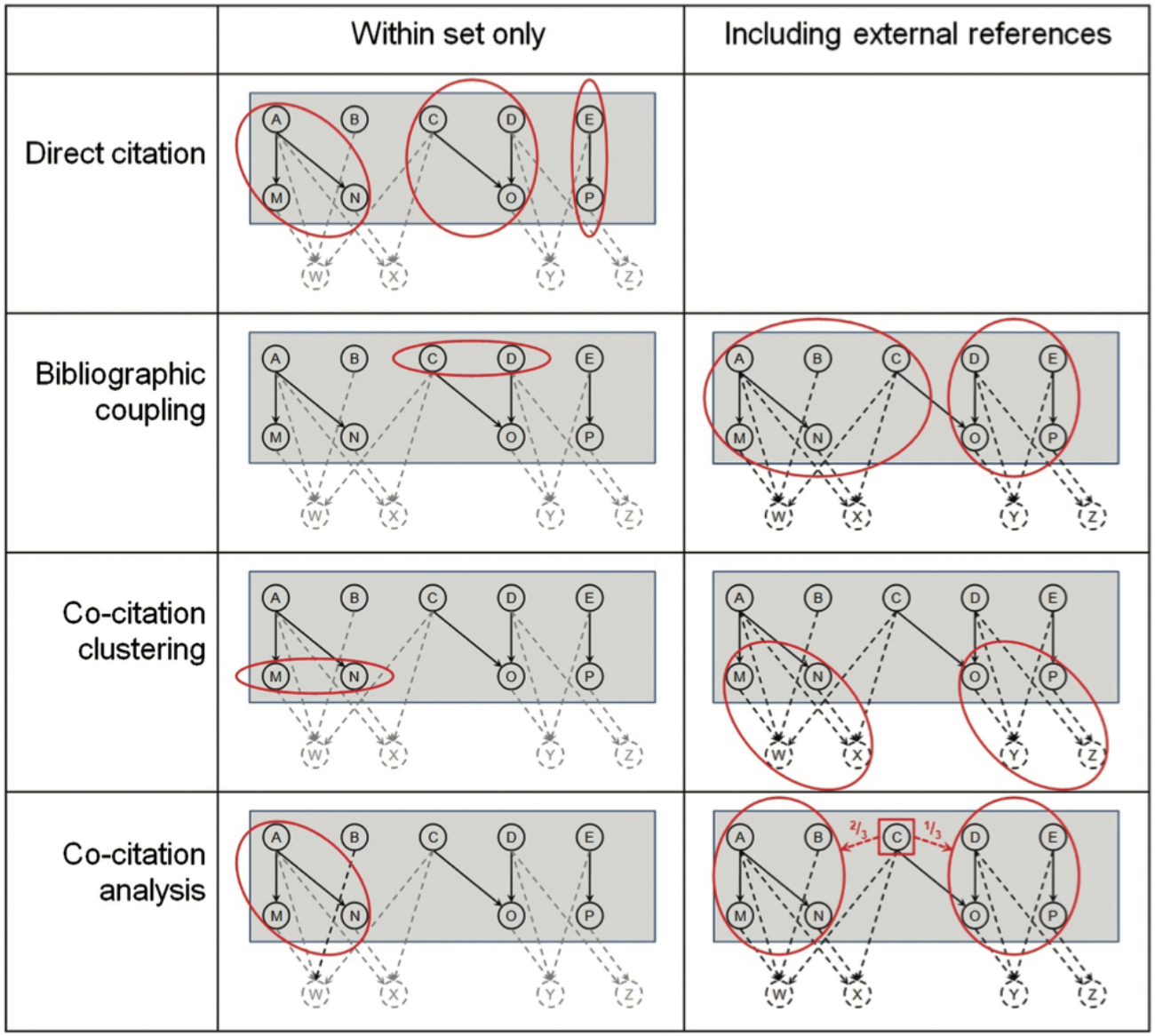
Mapping of cognitive connections

Citation analysis



Mapping of cognitive connections

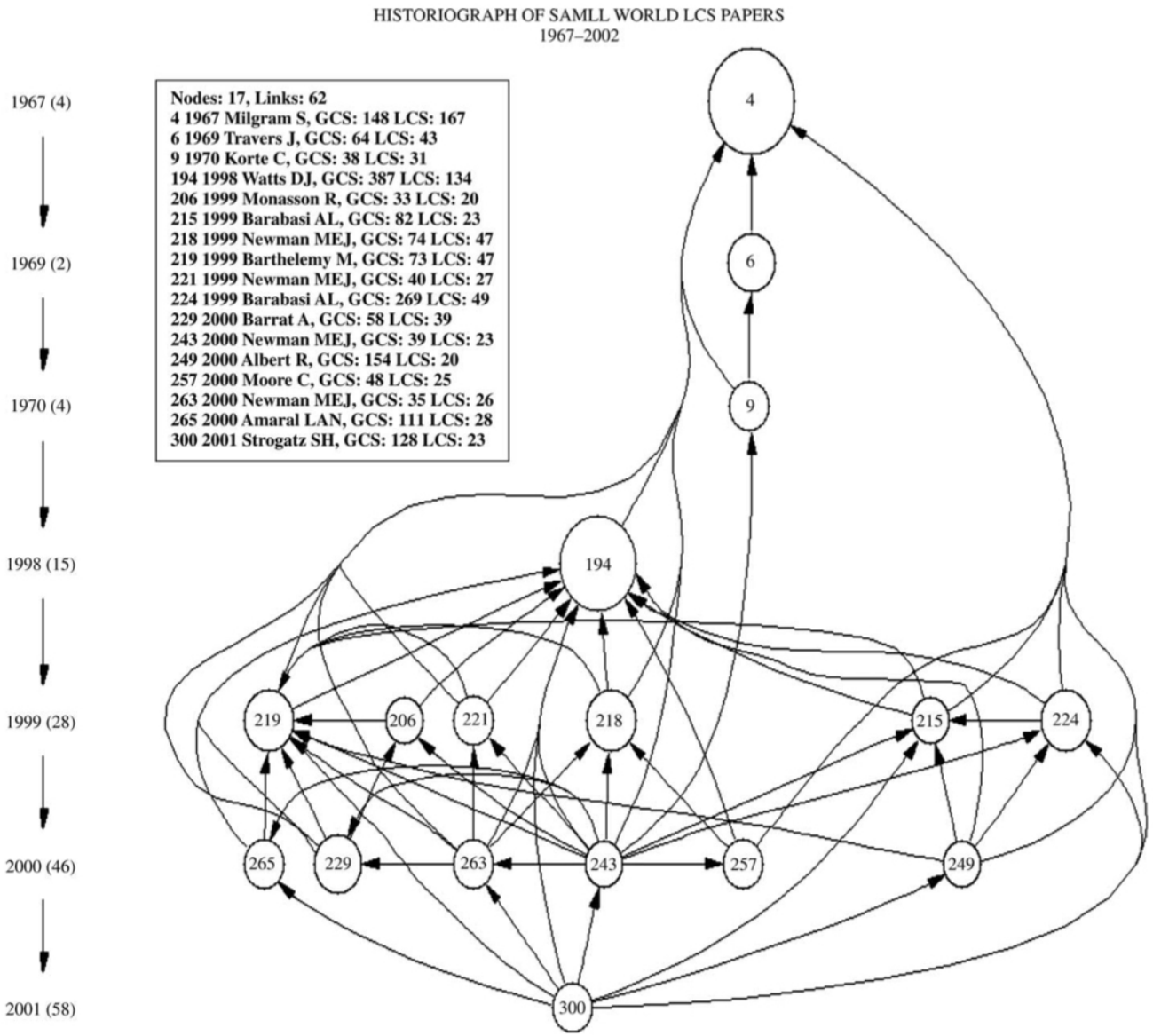
Citation analysis



Source: [Boyack and Klavans, 2010]

Mapping of cognitive connections

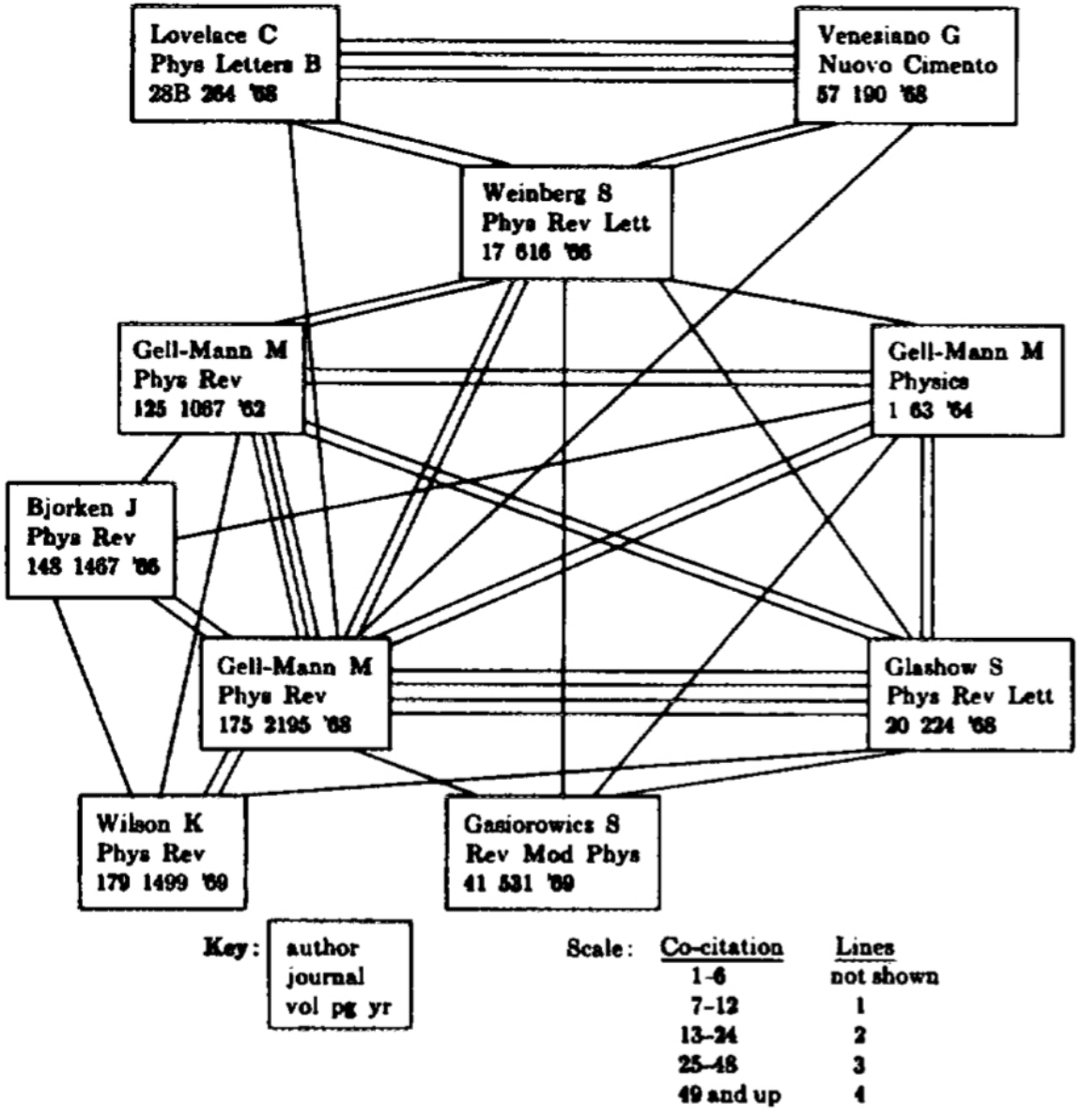
Direct citation analysis



Source: Literature on 'Small World' [Garfield, 2004]

Mapping of cognitive connections

Co-citation analysis

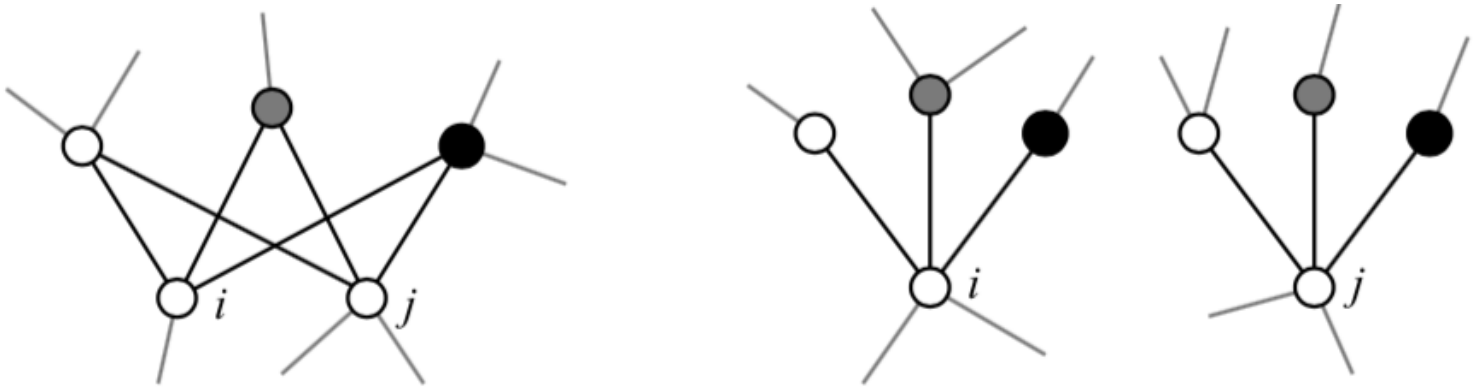


Source: Co-citation of frequently cited papers in particle physics [Small, 1973]

Mapping of cognitive connections

Structural equivalence vs. regular equivalence

- Structural equivalence: nodes that share many network neighbours (e.g. documents cited by the same set of documents)
- Regular equivalence: nodes that have neighbours that are similar to themselves (e.g. directors that have connections to their managers)



(a) Structural equivalence (b) Regular equivalence

Source: [Newman, 2010]

Mapping of cognitive connections

Cognitive distance

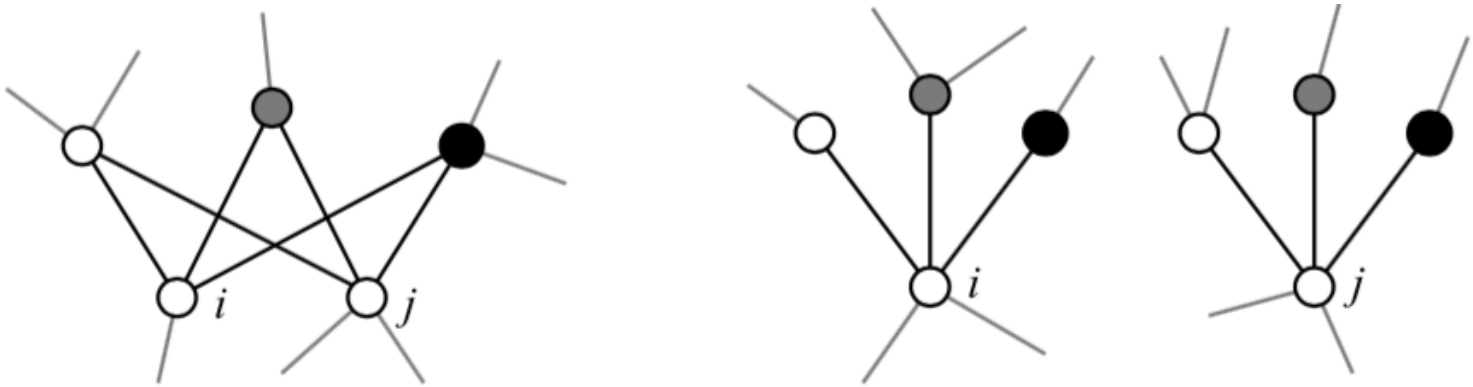
To calculate the weight of cognitive connections, we focus on structural equivalence:

Co-occurrence $= n_{ij} = \sum_k A_{ik} A_{kj}$

Euclidean distance $= d_{ij} = \sqrt{\sum_k (A_{ik} - A_{jk})^2}$

Cosine similarity or Salton's cosine $= \sigma_{ij} = \frac{\sum_k A_{ik} A_{kj}}{\sqrt{\sum_k A_{ik}^2} \sqrt{\sum_k A_{kj}^2}}$

Mapping of cognitive connections
Cognitive distance



(a) Structural equivalence (b) Regular equivalence

Source: [Newman, 2010]

Assuming the network to be undirected and unweighted:

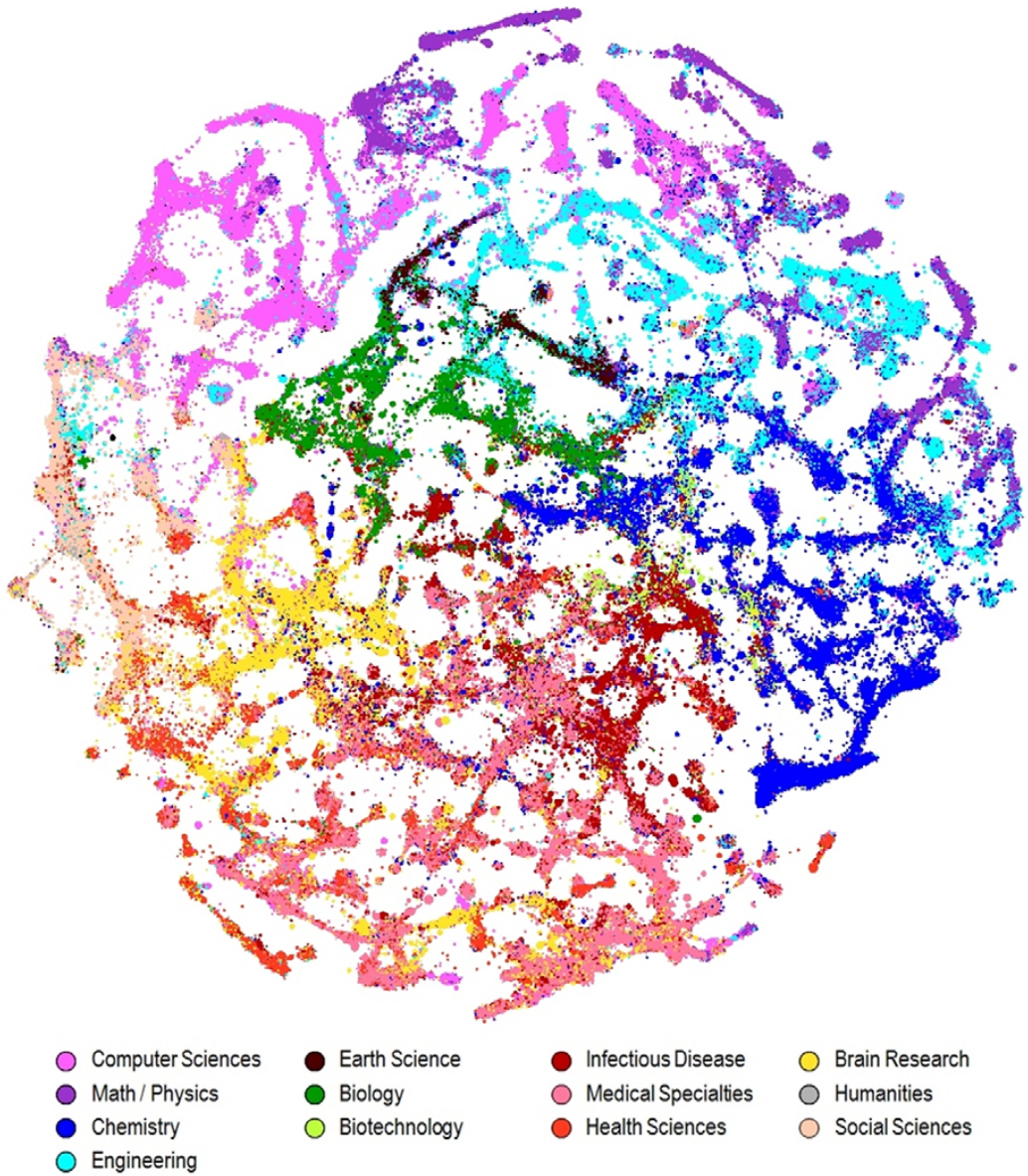
Co-occurrence $= n_{ij} = \sum_k A_{ik} A_{kj} = 3$

Euclidean distance $= d_{ij} = \sqrt{\sum_k (A_{ik} - A_{jk})^2} = \sqrt{3} = 1.73$

Cosine similarity or Salton's cosine $= \sigma_{ij} = \frac{\sum_k A_{ik} A_{kj}}{\sqrt{\sum_k A_{ik}^2} \sqrt{\sum_k A_{kj}^2}} = \frac{3}{\sqrt{4}\sqrt{5}} = 0.67$

Mapping of cognitive connections

Co-citation analysis



Source: Map of Science (+20M articles and +2M patents from 1996-2011) [Boyack et al., 2014]

Mapping of cognitive connections
Co-word analysis

We can extract terms/keywords

- Title
- Abstract
- List of keywords
- Full-text

Research Policy 44 (2015) 1827–1843

Contents lists available at ScienceDirect

Research Policy

journal homepage: www.elsevier.com/locate/respol

What is an emerging technology?

Daniele Rotolo [a,b,*], Diana Hicks [b], Ben R. Martin [a,c]

[a] SPRU – Science Policy Research Unit, University of Sussex, Brighton BN1 9SL, United Kingdom
[b] School of Public Policy, Georgia Institute of Technology, Atlanta 30332-0345, United States
[c] Centre for Science and Policy (CSAP) and Centre for Business Research, Judge Business School, University of Cambridge, Cambridge CB2 1QA, United Kingdom

ARTICLE INFO

Article history:
Received 11 December 2014
Received in revised form 15 June 2015
Accepted 16 June 2015

Keywords:
Emerging technologies
Conceptualisation
Definition
Attributes of emergence
Operationalisation
Detection and analysis
Framework
Scientometrics
Indicators
Science and Technology Studies (STS)

ABSTRACT

There is considerable and growing interest in the emergence of novel technologies, especially from the policy-making perspective. Yet, as an area of study, emerging technologies lack key foundational elements, namely a consensus on what classifies a technology as 'emergent' and strong research designs that operationalise central theoretical concepts. The present paper aims to fill this gap by developing a definition of 'emerging technologies' and linking this conceptual effort with the development of a framework for the operationalisation of technological emergence. The definition is developed by combining a basic understanding of the term and in particular the concept of 'emergence' with a review of key innovation studies dealing with definitional issues of technological emergence. The resulting definition identifies five attributes that feature in the emergence of novel technologies. These are: (i) radical novelty, (ii) relatively fast growth, (iii) coherence, (iv) prominent impact, and (v) uncertainty and ambiguity. The framework for operationalising emerging technologies is then elaborated on the basis of the proposed attributes. To do so, we identify and review major empirical approaches (mainly in, although not limited to, the scientometric domain) for the detection and study of emerging technologies (these include indicators and trend analysis, citation analysis, co-word analysis, overlay mapping, and combinations thereof) and elaborate on how these can be used to operationalise the different attributes of emergence.

1. Introduction

Emerging technologies have been the subject of much debate in academic research and a central topic in policy discussions and initiatives. Evidence of the increasing attention being paid to the phenomenon of emerging technologies can be found in the growing number of publications dealing with the topic and news articles mentioning emerging technologies (in their headlines or lead paragraphs), as depicted in Fig. 1. Increasing policy interest in emerging technologies, however, must be set against a literature where no consensus has emerged as to what qualifies a technology to be emergent. Definitions proposed by a number of studies overlap, but also point to different characteristics. For example, certain definitions emphasise the potential impact emerging technologies are capable of exerting on the economy and society (e.g. Porter et al., 2002), especially when they are of a more 'generic' nature (Martin, 1995), while others give great importance to the uncertainty associated with the emergence process (e.g. Boon and Moors, 2008) or to the characteristics of novelty and growth (e.g. Small et al., 2014). The understanding of emerging technologies also depends on the analyst's perspective. An analyst may consider a technology emergent because of its novelty and expected socio-economic impact, while others may see the same technology as a natural extension of an existing technology. Also, emerging technologies are often grouped together under 'general labels' (e.g. nanotechnology, synthetic biology), when they might be better treated separately given their different socio-technical features (e.g. technical difficulties, involved actors, applications, uncertainties).

The lack of consensus over definitions is matched by an 'eclectic' and *ad hoc* approach to measurement. A wide variety of methodological approaches have been developed, especially by the scientometric community, for the detection and analysis of emergence in science and technology domains (e.g. Porter and Detampel, 1995; Boyack et al., 2014; Glänzel and Thijs, 2012). These methods, favoured, because they take advantage of growing computational power and large new datasets and allow one to work with more sophisticated indicators and models, lack strong connections to well thought out concepts that one is attempting to measure, a basic

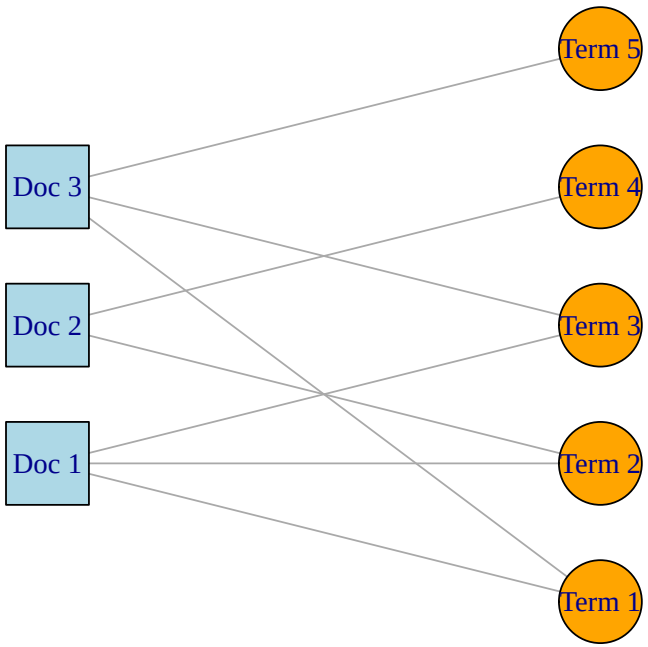
* Corresponding author at: SPRU – Science Policy Research Unit, University of Sussex, Brighton BN1 9SL, United Kingdom. Tel.: +44 1273 872980.
E-mail addresses: d.rotolo@sussex.ac.uk (D. Rotolo), diana.hicks@pubpolicy.gatech.edu (D. Hicks), b.martin@sussex.ac.uk (B.R. Martin).

http://dx.doi.org/10.1016/j.respol.2015.06.006
0048-7333/

Source: [?]

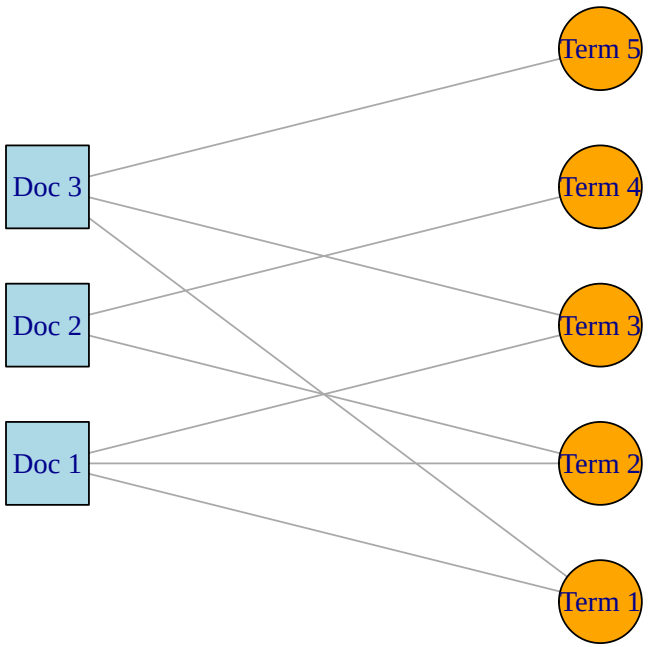
Mapping of cognitive connections

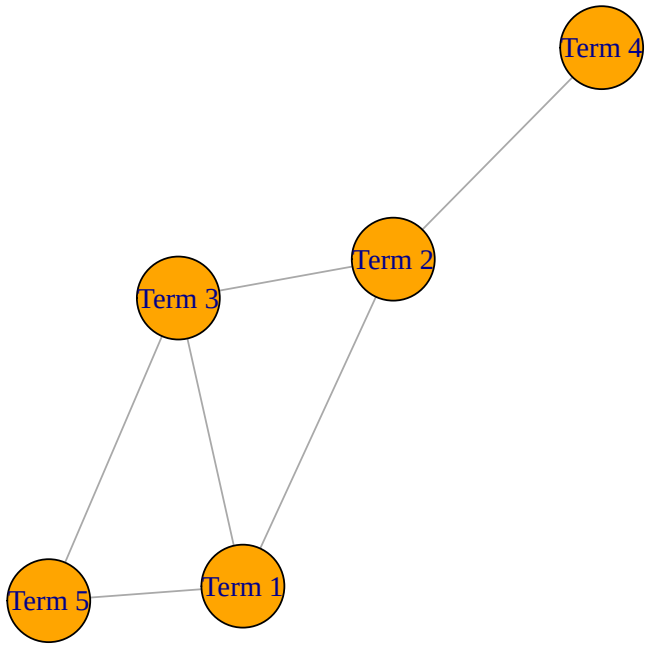
Co-word analysis



Mapping of cognitive connections

Co-word analysis



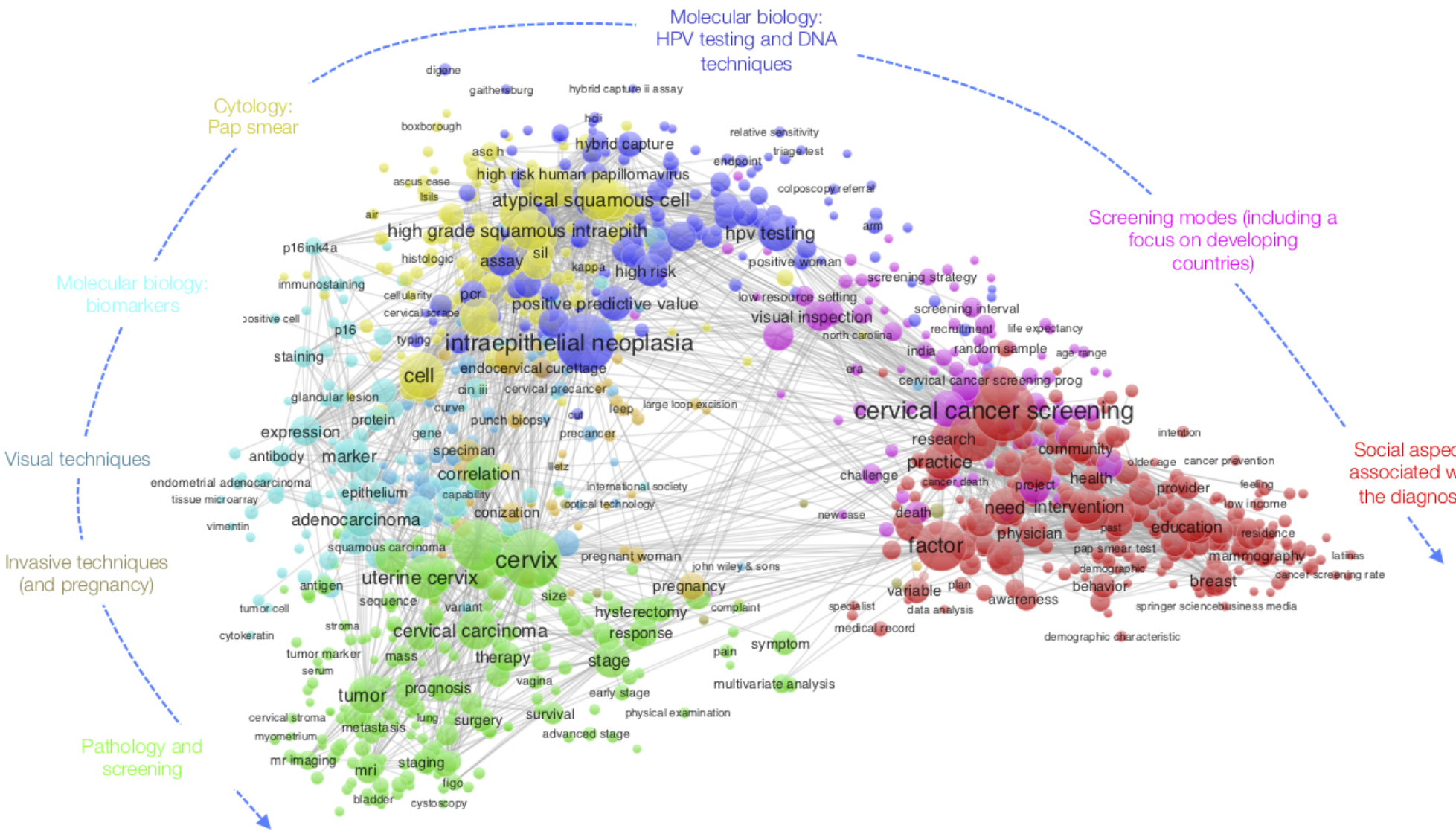


Distances between terms using

- co-occurrence
- euclidean distance
- cosine similarity
- ...

Mapping of cognitive connections

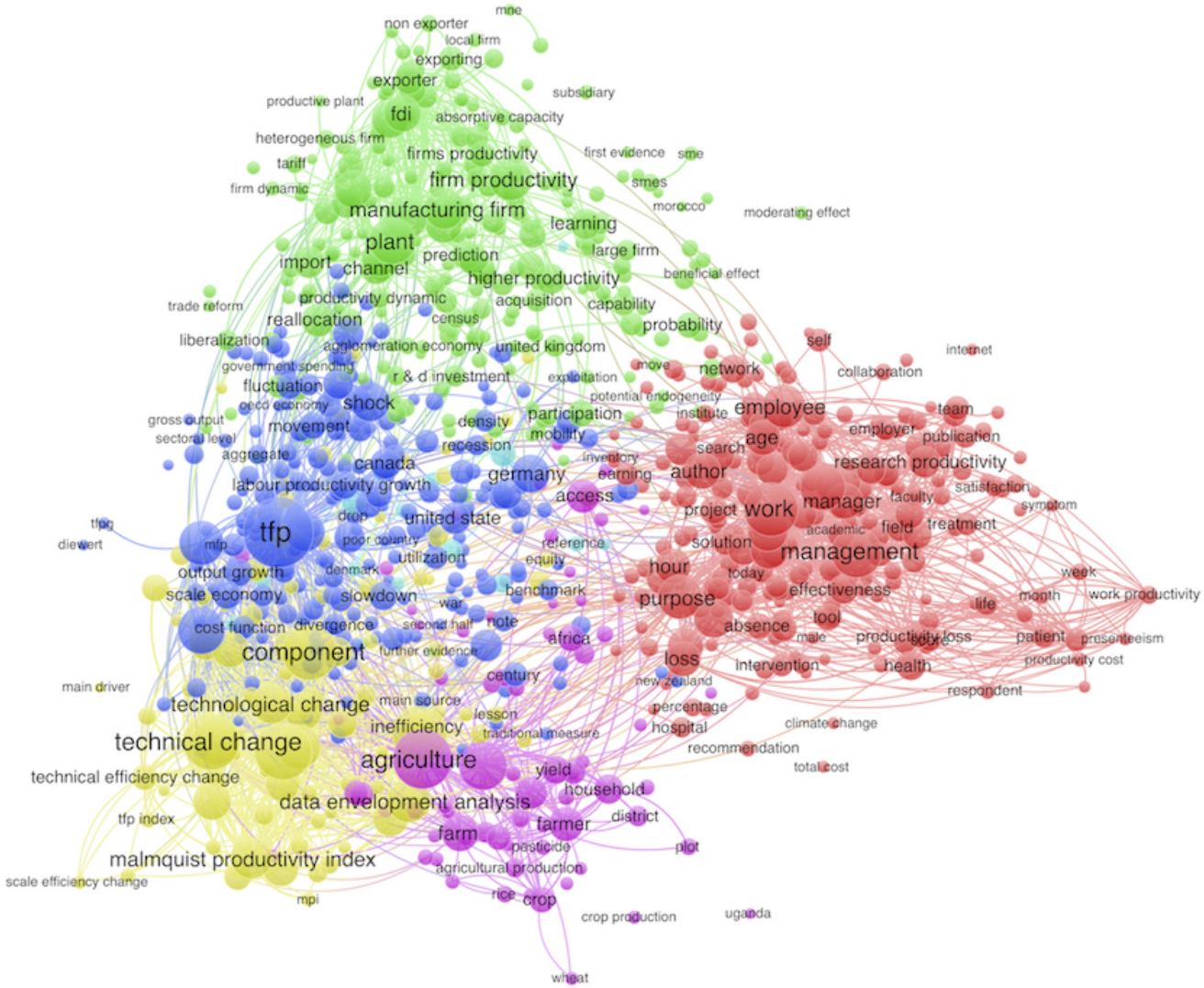
Co-word analysis



Source: Terms extracted from the titles and abstracts of 4,921 publications on the diagnosis of cervical cancer (1980-2011 period)

Mapping of cognitive connections

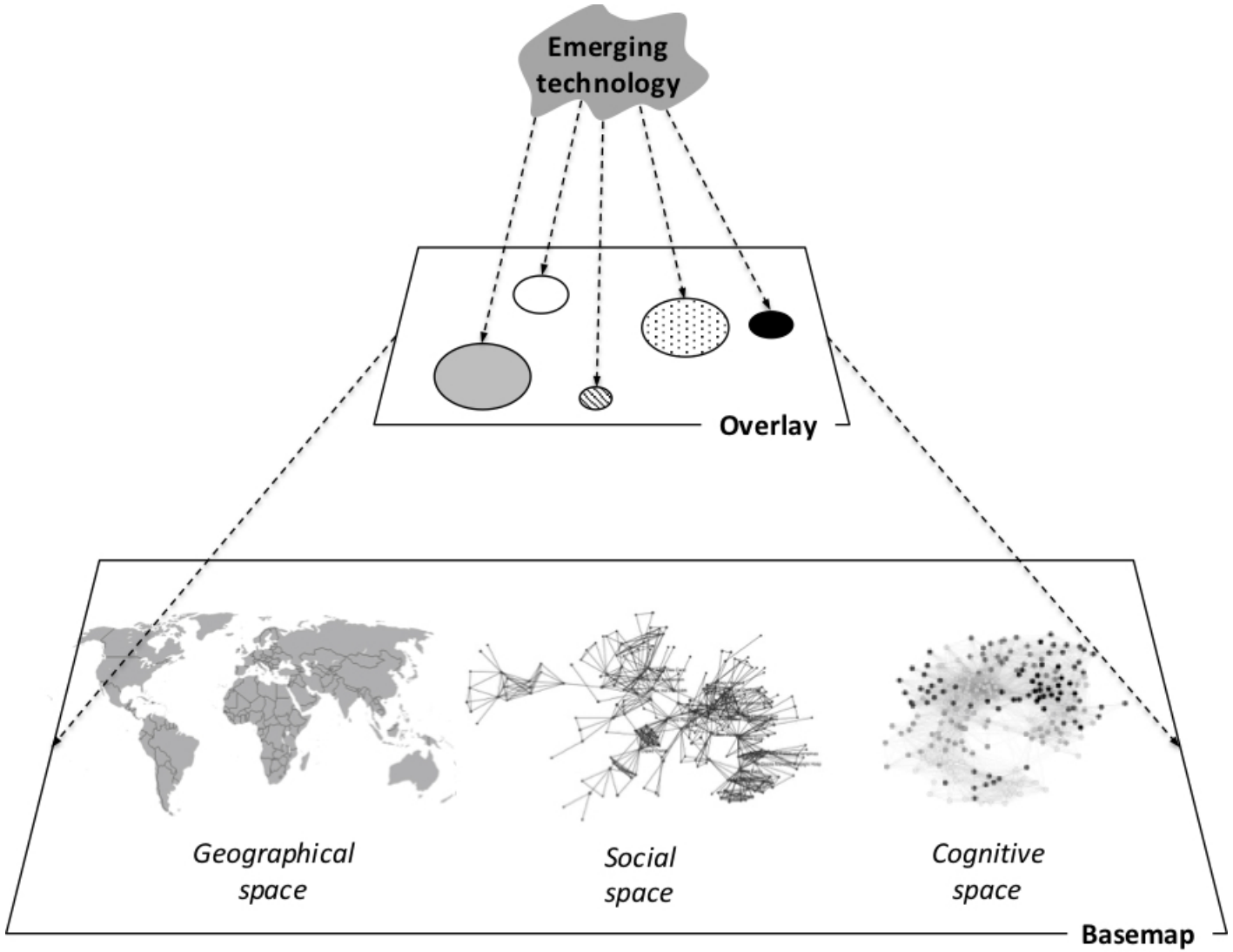
Co-word analysis



Source: Terms extracted from the titles and abstracts of 6,676 articles in business, management, and economics research areas that included the term "productivity" in their titles (1957-2016 period)

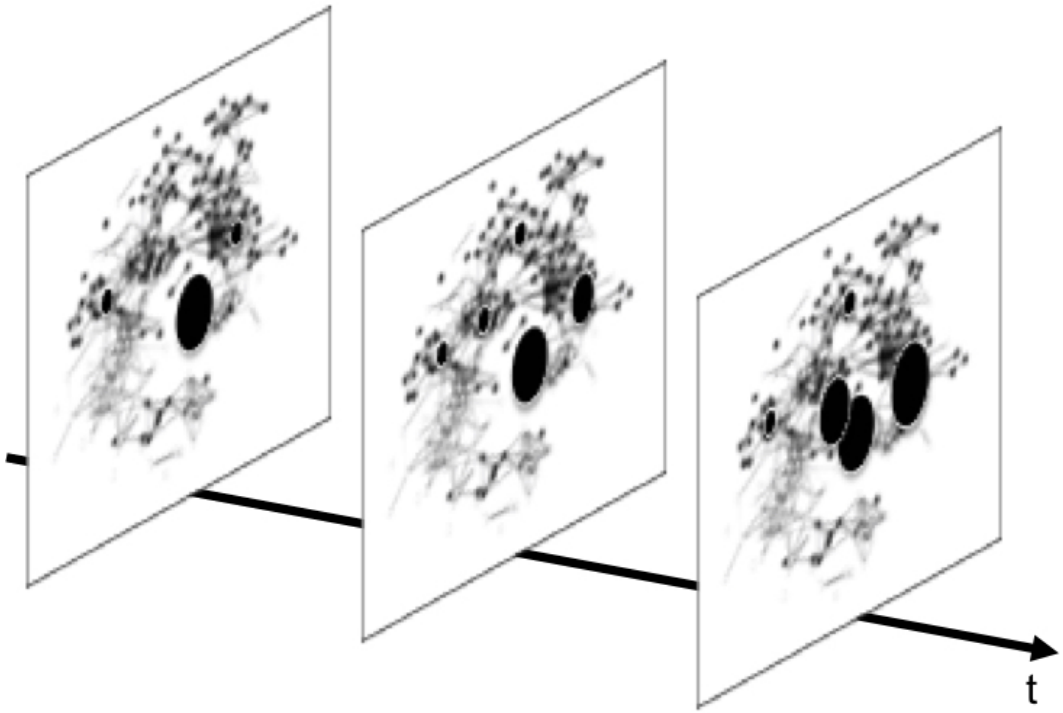
Mapping of cognitive connections

Overlay mapping



Source: Overlay mapping [Rotolo et al., 2017]

Mapping of cognitive connections
Overlay mapping



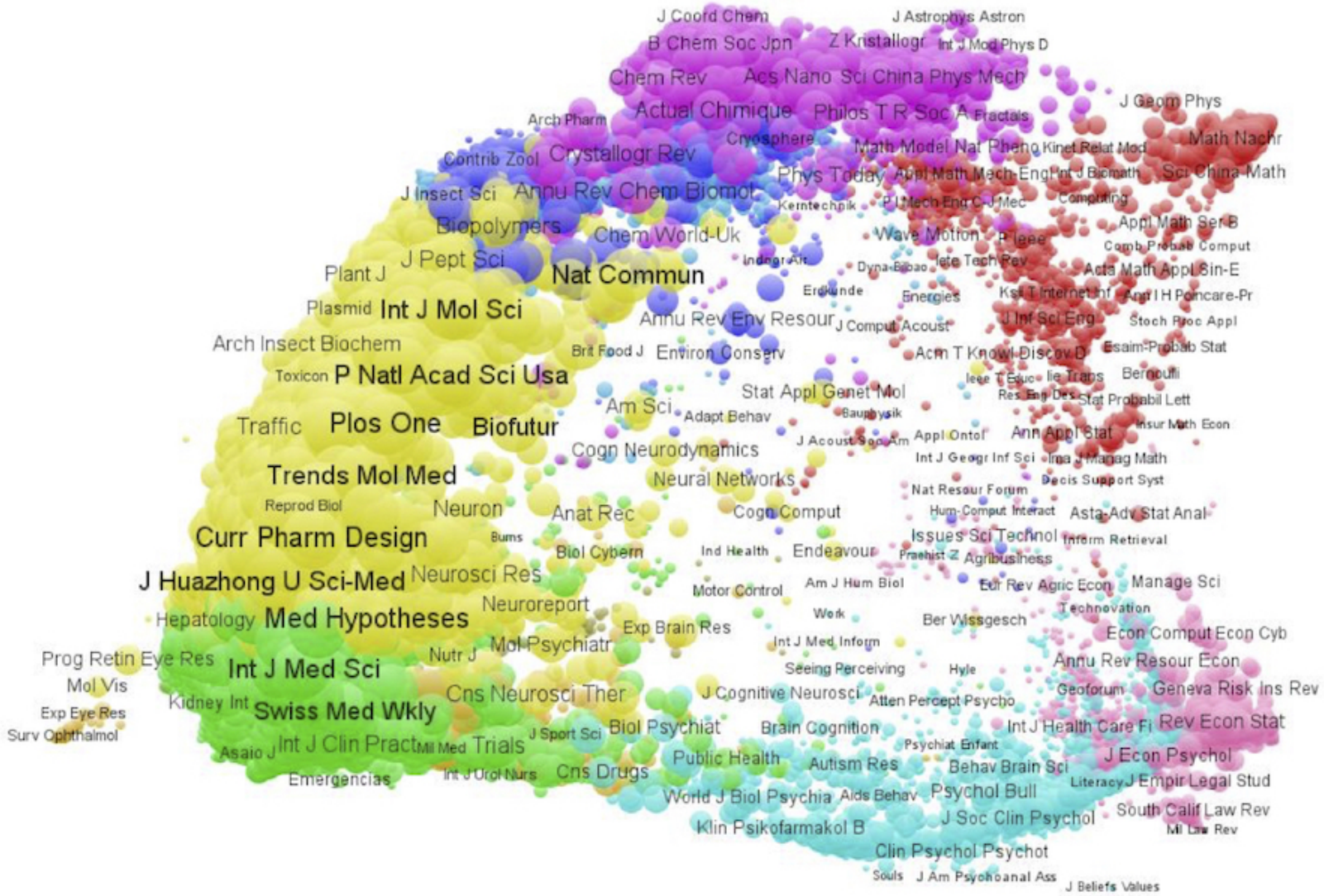
Source: Overlay mapping [Rotolo et al., 2017]

A number of basemaps have been generated [Rotolo et al., 2017]

- Geographical maps (e.g. Google Maps)
- Disciplines (Subject Categories oft Web of Science)
- Journals map
- MeSH (Medical Subject Headings) map
- IPC technological classes map (for patent data)

Mapping of cognitive connections

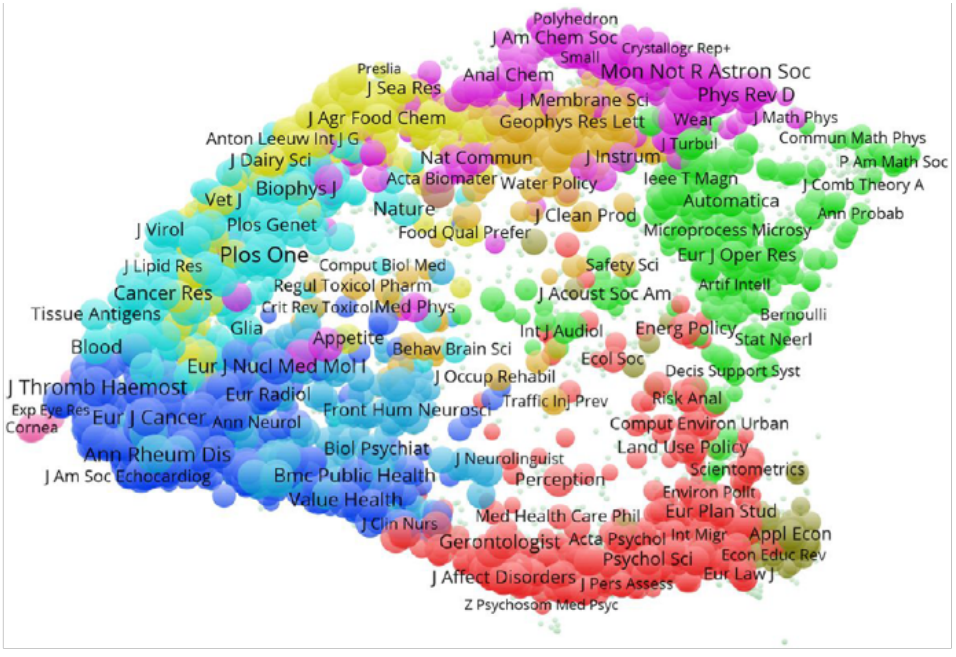
Overlay mapping



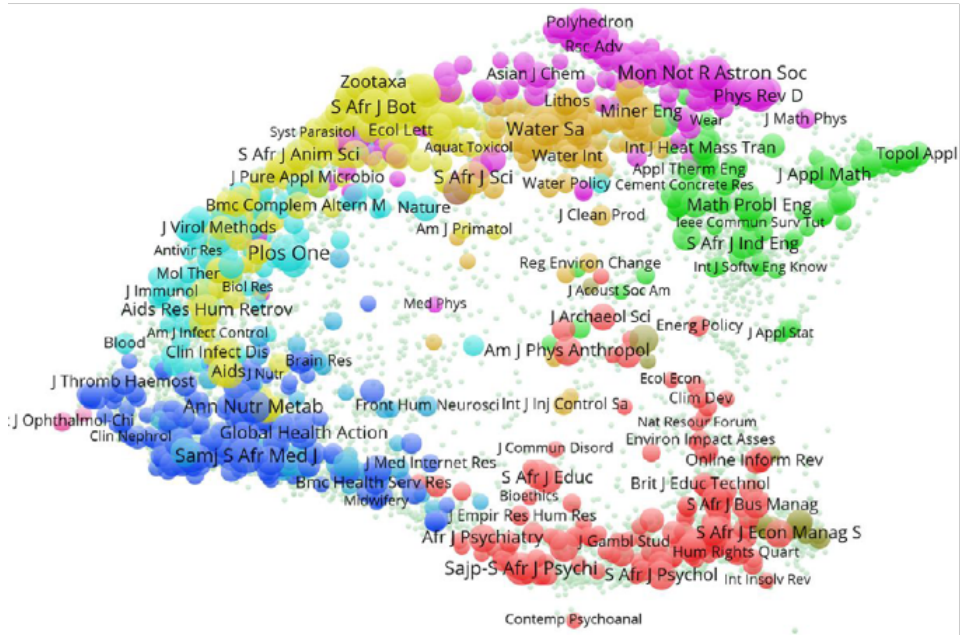
Source: Journal basemap (+10,000 journals) [Leydesdorff and Rafols, 2012]

Mapping of cognitive connections

Overlay mapping



Netherlands (2013)

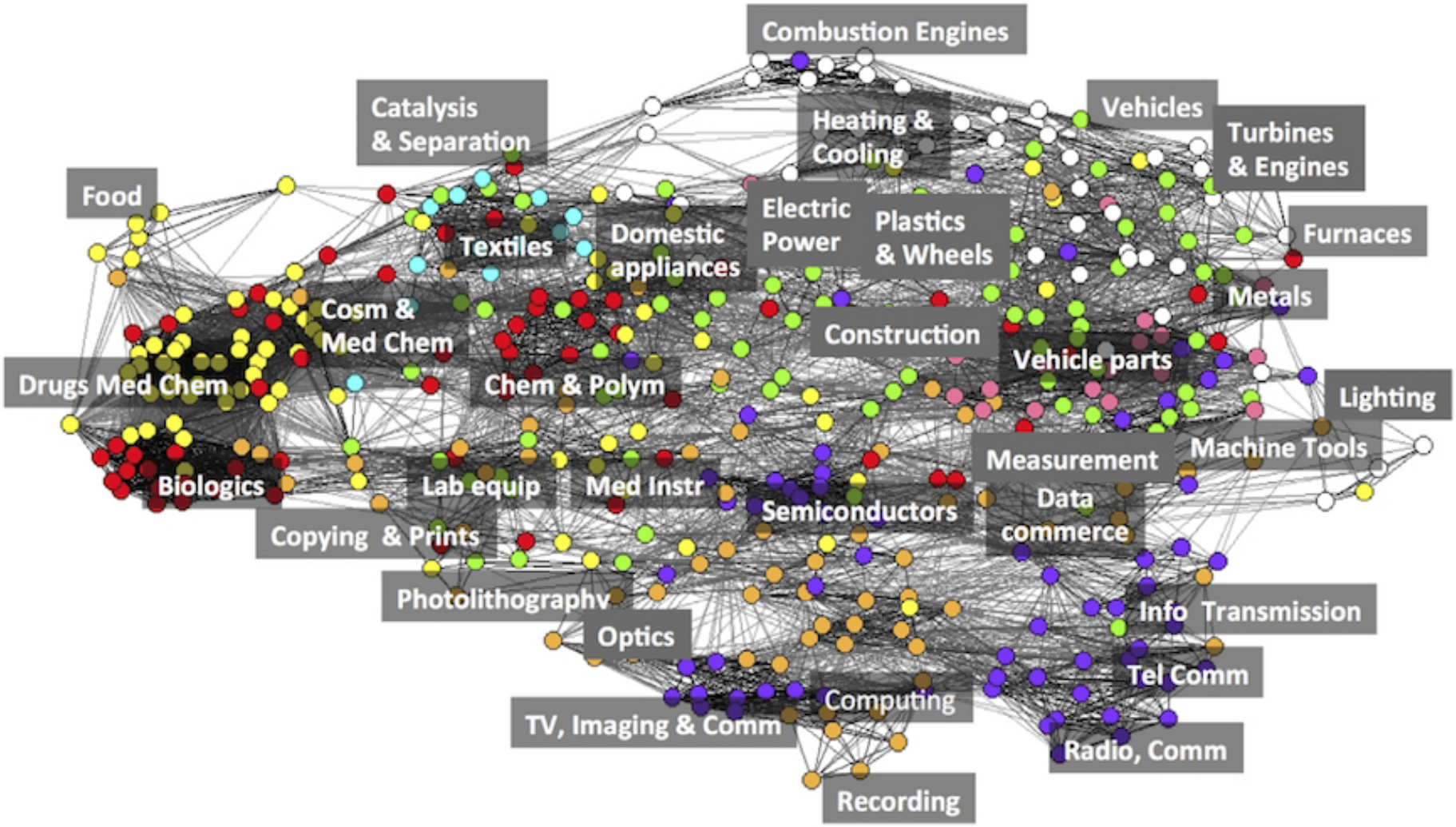


South Africa (2013)

Source: Journal overlay map [Leydesdorff et al., 2016]

Mapping of cognitive connections

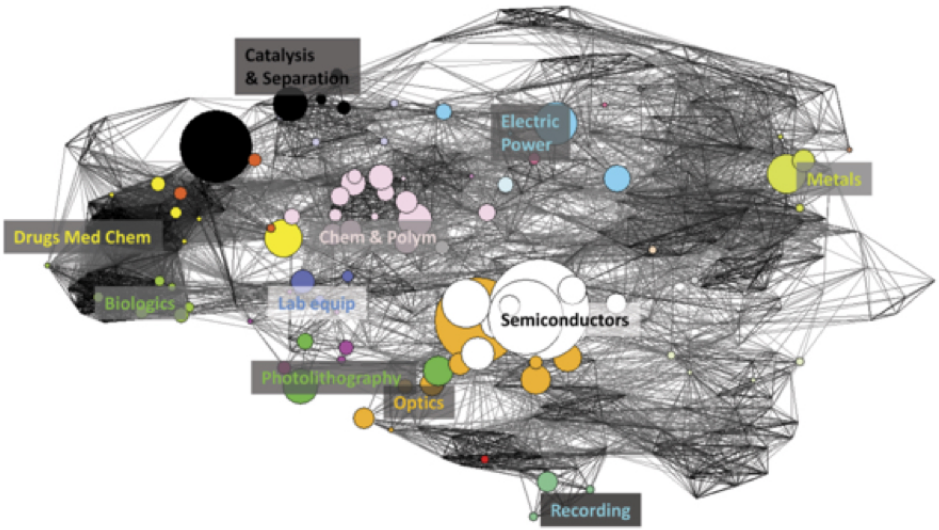
Overlay mapping



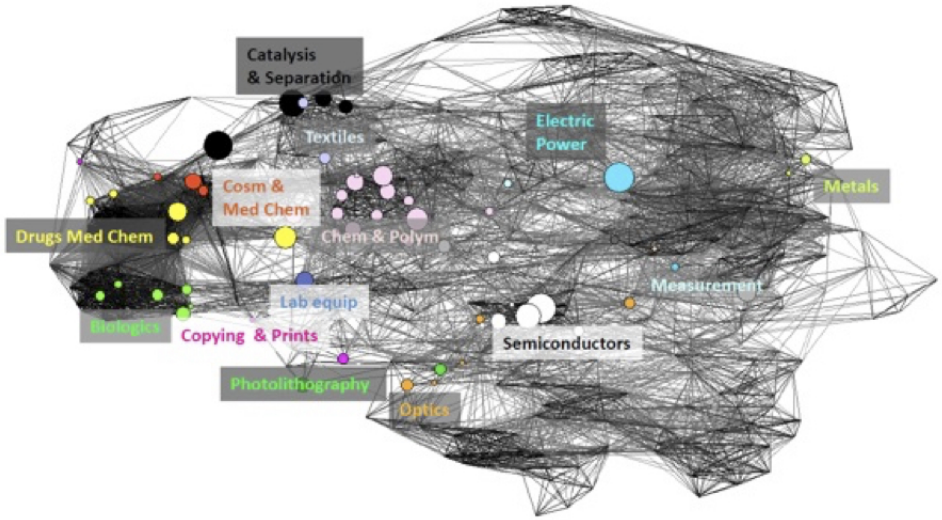
Source: Patent basemap (466 IPC) [Kay et al., 2014]

Mapping of cognitive connections

Overlay mapping



Samsung



Dupont

Source: Patent basemap and overlays [Kay et al., 2014]

Questions

Next time ...

Next time ...

- **Seminar: Innovation networks**
  - Practice with VOSViewer
- **Lecture: Social network theories**
  - Social capital
  - Strength of weak ties
  - Structural holes

References I

Ahn, Y.-Y., Ahnert, S. E., Bagrow, J. P., and Barabási, A.-L. (2011).

Flavor network and the principles of food pairing.
Scientific reports, 1:196.

Albert, R. and Barabasi, A. L. (2002).

Statistical mechanics of complex networks.
Reviews of Modern Physics, 74(1):47–97.

Boyack, K. W. and Klavans, R. (2010).

Co-citation analysis, bibliographic coupling, and direct citation: Which citation approach represents the research front most accurately?
Journal of the American Society for Information Science and Technology, 61(12):2389–2404.

Boyack, K. W., Klavans, R., Small, H., and Ungar, L. (2014).

Characterizing the emergence of two nanotechnology topics using a contemporaneous global micro-model of science.
Journal of Engineering and Technology Management - JET-M, 32:147–159.

Broadus, R. N. (1987).

Toward a definition of "bibliometrics".
Scientometrics, 12(5-6):373–379.

Callon, M., Courtial, J.-P., Turner, W. A., and Bauin, S. (1983).

From translations to problematic networks: An introduction to co-word analysis.
Social Science Information, 22(2):191–235.

de Solla Price, D. J. (1963).

Little Science, Big Science.
Columbia University Press, New York, NY, USA.

DeMuth, P. C., Min, Y., Huang, B., Kramer, J. a., Miller, A. D., Barouch, D. H., Hammond, P. T., and Irvine, D. J. (2013).

Polymer multilayer tattooing for enhanced DNA vaccination.
Nature materials, 12(4):367–76.

References II

Garfield, E. (2004).

Historiographic mapping of knowledge domains literature.
Journal of Information Science, 30(2):119–145.

Garfield, E., Ph, D., Sher, I. H., and Sc, D. (1964).

the Use of Citation Data.
Number 64. Institute for Scientific Information, Philadelphia.

Hess, D. J. (1997).

Science Studies: An Advanced Introduction.
NYU Press, New York, NY, USA.

Katz, J. and Martin, B. R. (1997).

What is research collaboration?
Research Policy, 26(1):1–18.

Kay, L., Newman, N., Youtie, J., Porter, A. L., and Rafols, I. (2014).

Patent overlay mapping: Visualizing technological distance.
Journal of the Association for Information Science and Technology, 65(12):2432–2443.

Kessler, M. (1963).

Bibliographic Coupling Between Scientific Papers.
American documentation, 14(1):10–25.

Leydesdorff, L., Heimeriks, G., and Rotolo, D. (2016).

Journal portfolio analysis for countries, cities, and organizations: Maps and comparisons.
Journal of the Association for Information Science and Technology, 67(3):741–748.

Leydesdorff, L. and Rafols, I. (2012).

Interactive overlays: A new method for generating global journal maps from Web-of-Science data.
Journal of Informetrics, 6(2):318–332.

References III

Melin, G. and Persson, O. (1996).

Studying research collaboration using co-authorships.
Scientometrics, 36(3):363–377.

Moody, J. (2004).

The structure network of a social science: Collaboration disciplinary cohesion from 1963 to 1999.
American Sociological Review, 69(2):213–238.

Newman, M. (2010).

Networks. An introduction.
Oxfor University Press, Oxford, UK.

Newman, M. E. (2001).

The structure of scientific collaboration networks.
Proceedings of the National Academy of Sciences of the United States of America, 98(2):404–9.

Rafols, I., Porter, A. L., and Leydesdorff, L. (2010).

Science Overlay Maps: A new tool for research policy and library management.
Journal of the American Society for Information Science and Technology (JASIST), 61(9):1871–1887.

Rotolo, D., Hicks, D., and Martin, B. R. (2015).

What is an emerging technology?
Research Policy, 44(10):1827–1843.

Rotolo, D., Rafols, I., Hopkins, M., and Leydesdorff, L. (2017).

Strategic intelligence on emerging technologies: Scientometric overlay mapping.
Journal of the Association for Information Science and Technology, 68(1):214–233.

Small, H. G. (1973).

Co-citation in the Scientific Literature : A New Measure of the Relationship Between Two Documents.
Journal of the American Society for Information Science, 24(4):265–269.