Science Mapping: Convergence, Consensus, Policy Implications?

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Overview

- Accuracy studies
- Overview of 2 recent papers
  - Convergence or consensus?
    - Comparison of 20 maps of science
    - Submitted to *JASIST* (under review)
  - Linking science/technology through inventor-authors
    - Using rare names
    - Accepted for publication in *Journal of Informetrics*
- Simplified circle map and uses

Accuracy is critical

- Use of science maps for policy requires that they be as accurate as possible
  - If metrics or rankings are to be used, this is also true for any science classification structure, regardless of whether it is “mapped” or not
- We have done several accuracy studies
  - Journal maps: explored the local and regional accuracy of different similarity measures using ISI categories as a standard
  - Paper-level maps: explored local accuracy and disciplinary bias of two similarity measures, and two levels of pruning
  - In general, normalized similarity measures show reasonable agreement with category structures

Accuracy studies have limitations

- Is there a single map of science or classification structure?
  - Some conversation between Börner, Boyack, Leydesdorff, Rosvall, Small, and others several months ago ended up with a “NO”
  - Multi-dimensional system, any single map might miss important facets
  - Disagreement on whether we should even try to come to some “convergence” or not
- So, where do we go next, given that
  - There is no single accepted map
  - There is no fully accepted standard

Is there a case for convergence?

- We decided to compare/contrast all of the "comprehensive" maps of science that we could find
- We found 20 in the following categories
  - Hand-drawn (4)
    - 3 by experts
    - 1 based on course pre-requisites
  - Electronic (16)
    - 6 reference paper maps
    - 7 journal maps
    - 3 journal category maps

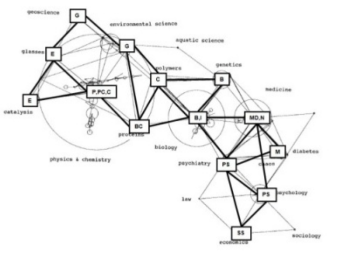
Maps and references

Researcher(s) & Reference	Name	Method	Elements	# Clust	Database & Year	Form
(Bernal, 1939)	Bernal	Expert		14, 110		Hierarchical
(Ellingham, 1948)	Ellingham	Expert		13, 51, 130		Hierarchical & Non-centric
(Balaban & Klein, 2006)	Balaban-I	Expert	16 fields	16		Hierarchical & Centric
(Griffith, Small, Stonehill, & Dey, 1974)	Small74	Reference papers	1,150 pap	41	SC, 1972 Q1	Centric
(Small & Garfield, 1985)	Small85	Reference papers	~11,000 pap	51	SC+SS, 1983	Hierarchical & Centric
(Small, 1999)	Small99	Reference papers	36,720 pap	35	SC+SS, 1995	Hierarchical
(Klavans & Boyack, 2008)	KB-Para	Reference papers	800k pap	776	SC+SS, 2003	Non-centric
(Klavans & Boyack, 2007)	KB06-TS	Reference papers	1.9M pap	283	SC+SS, 2004	Non-centric
(Klavans & Boyack, 2007)	KB06-SC	Reference papers	2.1M pap	554	Scopus, 2004	Non-centric
(Bassecoulard & Zitt, 1999)	B-Z	Journals	~2,000 jnl	29	SC/JCR, 1993	Hierarchical & Centric
Klavans, unpublished, 2002	K02	Journals	5,647 jnl	69	SC+SS+AH, 2000	Non-centric
(Boyack, Klavans, & Börner, 2005)	Backbone	Journals	7,121 jnl	205	SC+SS, 2000	Non-centric
(Boyack et al., 2008)	BBK02-S	Journals	7,227 jnl	671	SC+SS, 2002	Non-centric
(Boyack, 2008)	B03-ST	Journals	8,667 jnl	852	SC+SS+PR, 2003	Non-centric
(Klavans, Patek, & Boyack, 2007)	UCSD	Journals	16,235 jnl	554	SC/SS/AH + Scopus, 2001-05	Non-centric
(Rosvall & Bergstrom, 2007)	Rosvall	Journals	6,116 jnl	87	SC+SS, 2004	Non-centric
(Moya-Anegón et al., 2004)	Scimago-I	Journal categories	25 categ	25	SC+SS+AH, 2000 Spanish papers	Non-centric
(Moya-Anegón et al., 2007)	Scimago-II	Journal categories	219 categ	219	SC+SS+AH, 2002	Centric
(Leydesdorff & Rafols, 2007)	L-R	Journal categories	6,164 jnl; 172 categ	172	SC, 2006	Mixed
(Balaban & Klein, 2006)	Balaban-II	Course prerequisites		11	Texas A&M undergraduate	Centric

Map forms

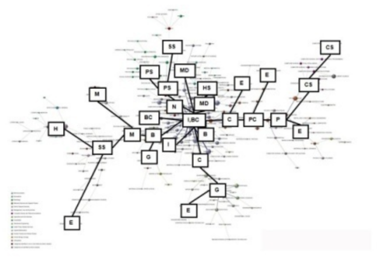
- Hierarchical (linear)
- Centric (hub/spokes)
- Non-centric (ring)

SMALL99 2 – Coding



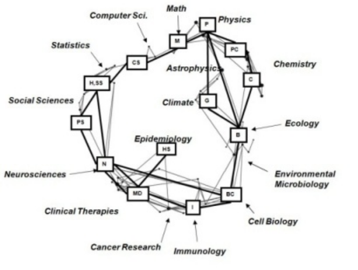
Small, H. (1999). Visualizing science by citation mapping. Journal of the American Society for Information Science, *50(9), 799-813.*

SCIm



Moya-Anegón, F., Vargas-Quesada, B., Chinchilla-Rodriguez, Z., Corera-Álvarez, E., Munoz-Fernández, F.J., & Herrero-Solana, V. (2007). Visualizing the marrow of science. Journal of the American Society for Information Science and Technology, 58(14), 2167-2179.

K02 2 – Coding



Klavans, R. (2003). Poster at the Sackler Colloquium on Mapping Knowledge Domains, Irvine, CA, May 9-11, 2003.

Comparing maps of science

- Maps all conform to the following:
  - Division (separation of science into parts)
  - Proximate location (related parts are adjacent)
  - Linkage (additional linkages for non-adjacent parts)
- Need a basis of comparison since all maps are at different levels of detail
- It was quickly determined that convergence was not happening, so we switched to looking for “consensus”

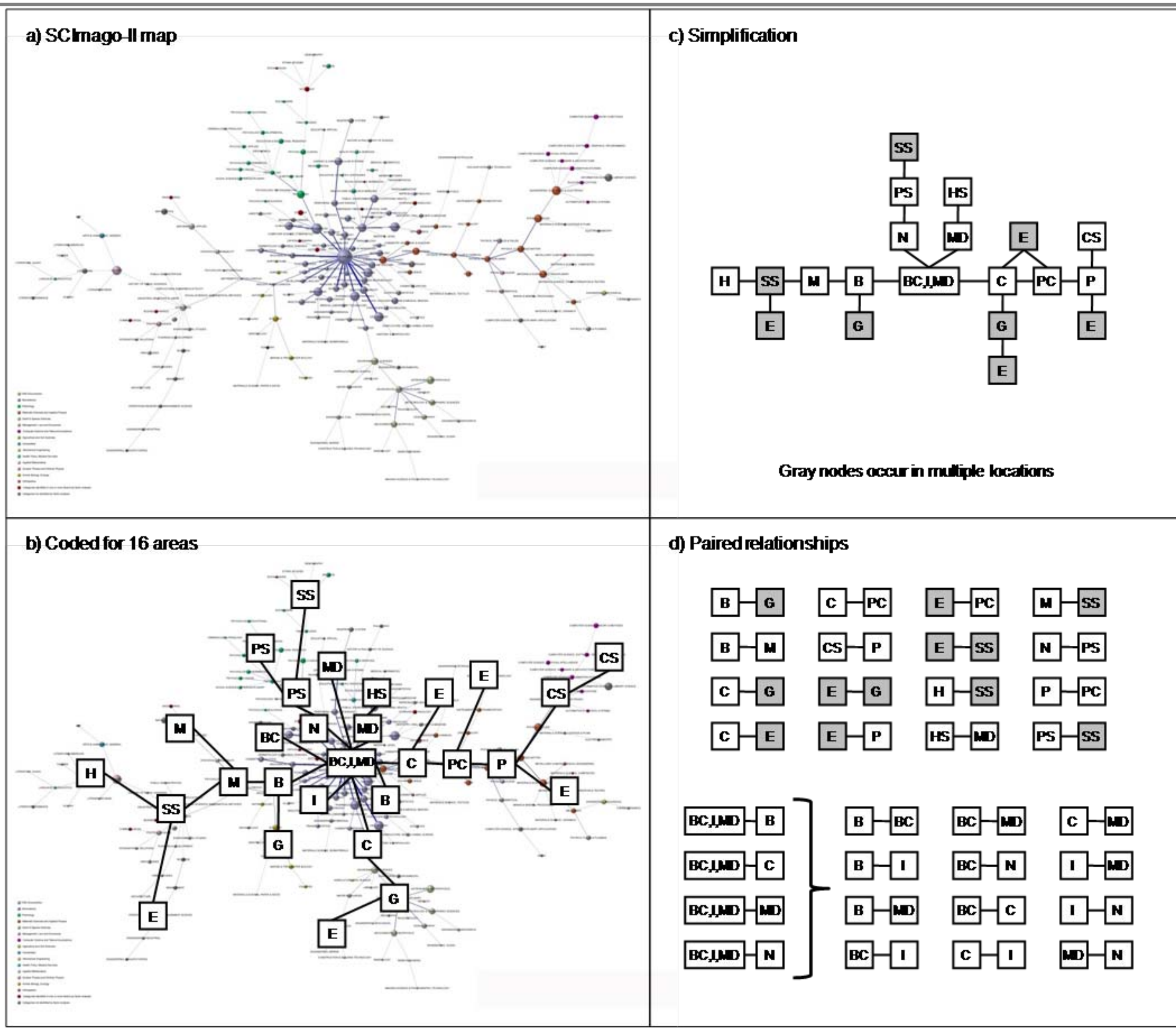
Procedure

- Develop a framework
- Code all maps using the framework
- Simplify each coded map (eliminate duplicate edges)
- List paired relationships
- Used paired relationships from all maps to determine consensus, and to measure relative accuracies of all maps

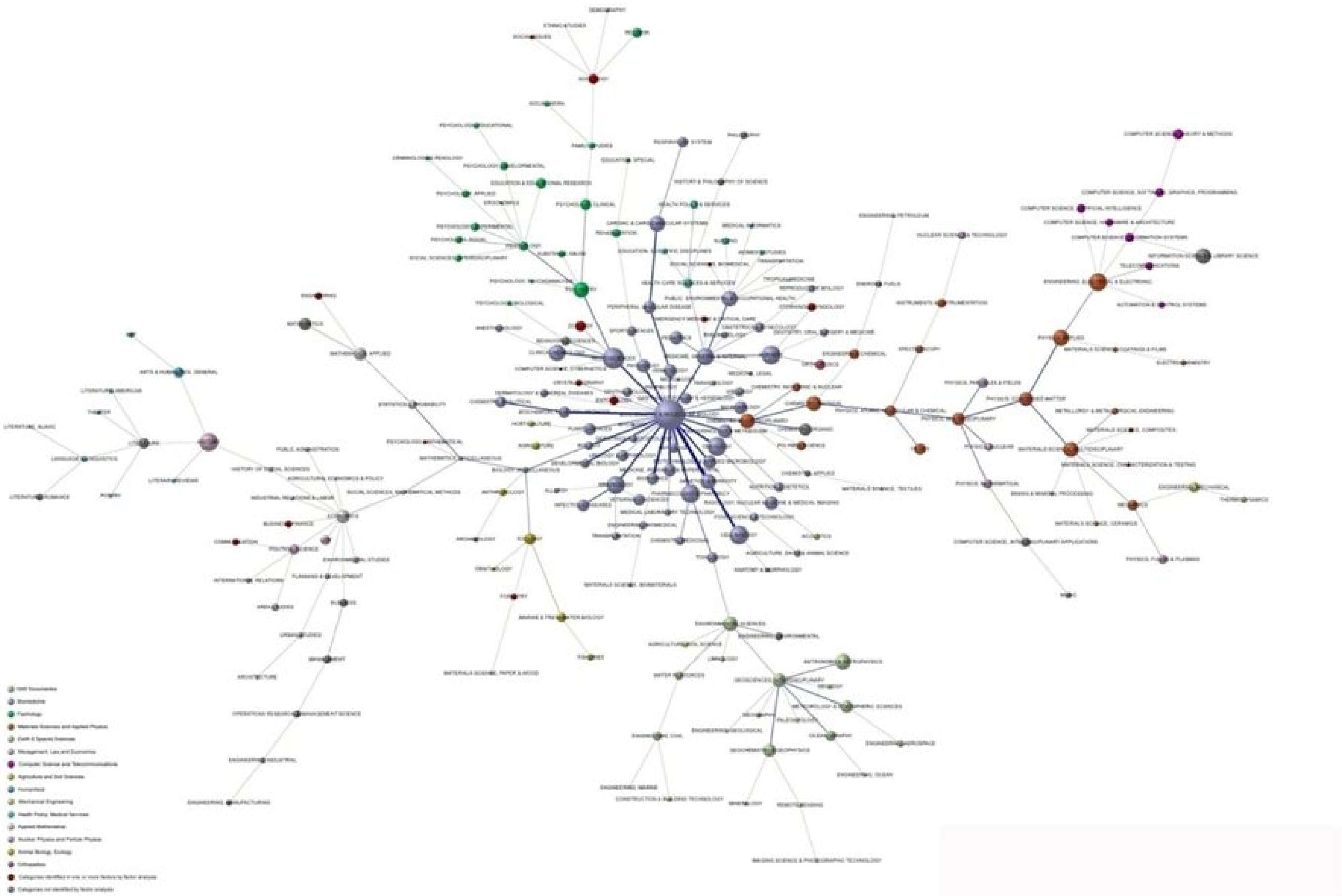
Framework

- Science was divided into 16 broad areas
  - Fundamental areas (4): Math, Physics, Chemistry, Biology mentioned in all maps
  - Fundamental combinations (2): Physical Chemistry, Biochemistry mentioned in most maps
  - Applied areas related to physics/chemistry (3): Computer Science, Engineering, Earth Sciences
  - Applied areas related to biology (3): Infectious Disease, Medical Specialties, Brain Research
  - Applied areas dealing with social issues (3): Social Sciences, Health Services, Psychology
  - AHCI (1): Humanities

Coding example

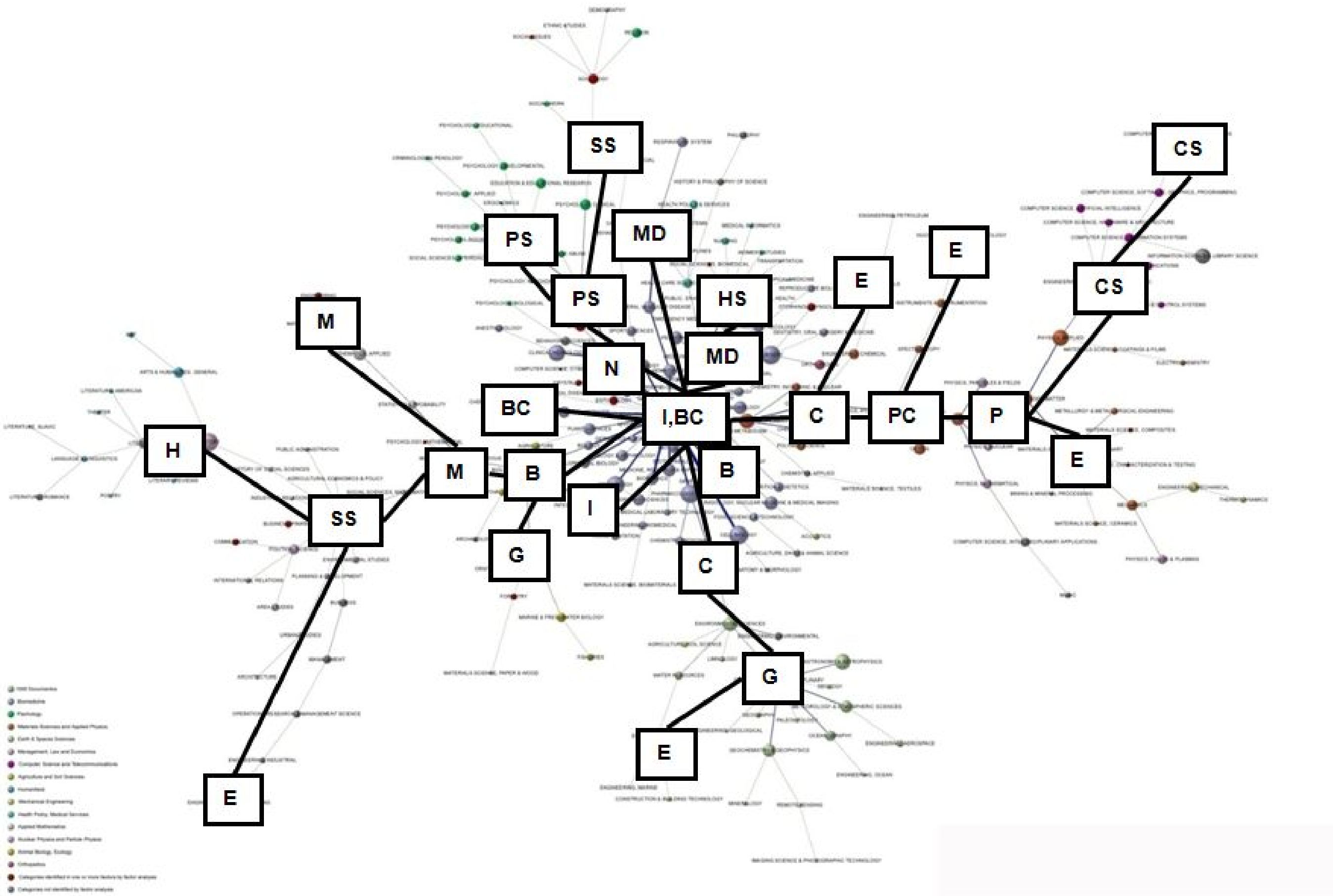


SCImago-II 1 – Map



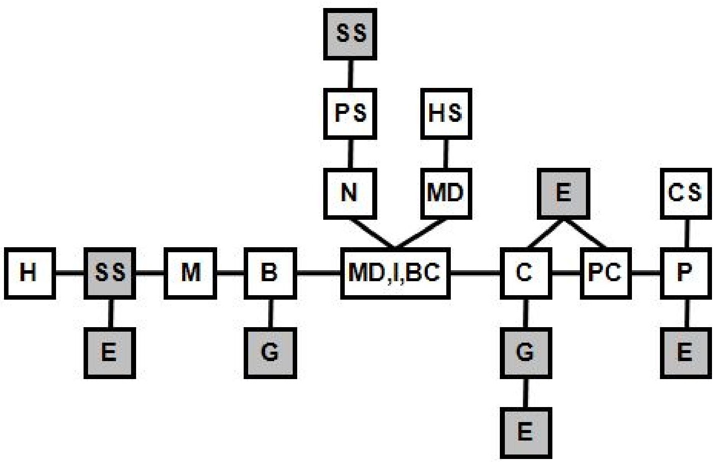
Moya-Anegón, F., Vargas-Quesada, B., Chinchilla-Rodríguez, Z., Corera-Álvarez, E., Munoz-Fernández, F.J., & Herrero-Solana, V. (2007). Visualizing the marrow of science. Journal of the American Society for Information Science and Technology, 58(14), 2167-2179.

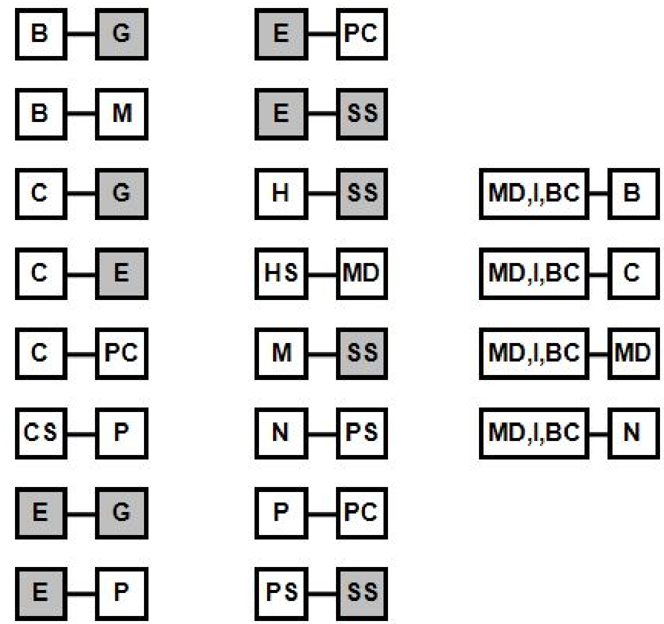
SCImago-II 2 – Coding



Moya-Anegón, F., Vargas-Quesada, B., Chinchilla-Rodríguez, Z., Corera-Álvarez, E., Munoz-Fernández, F.J., & Herrero-Solana, V. (2007). Visualizing the marrow of science. Journal of the American Society for Information Science and Technology, 58(14), 2167-2179.

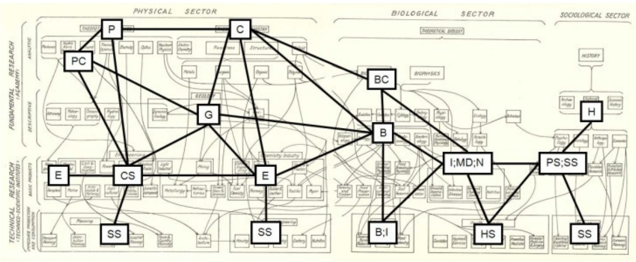
SCImago-II 3 – Simplification and edges





All maps and codings available at www.mapofscience.com/history/maps

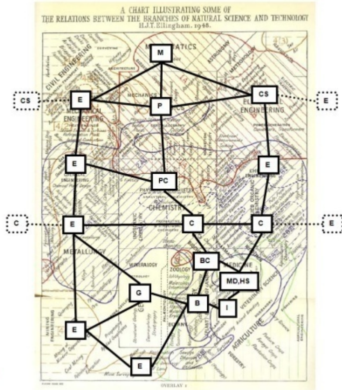
BERNAL 2 – Coding



Bernal, J.D. (1939). The social function of science. London: George Routledge & Sons Ltd.

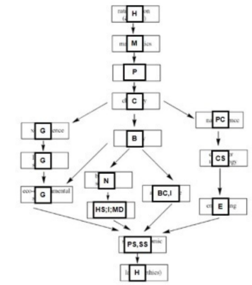
ELLINGHAM 2 – Coding

The map is actually a cylinder (edge on the left is connected to edge on the right), according to Ellingham in his original paper. See, for example, chemical engineering appearing on left and right of map.



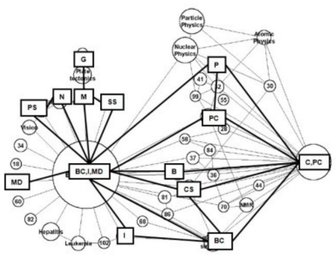
Ellingham, H.J.T. (1948). Divisions of natural science and technology, The Royal Society Scientific Information Conference (pp. 477-484): The Royal Society, Burlington House.

BALABAN-I 2 – Coding



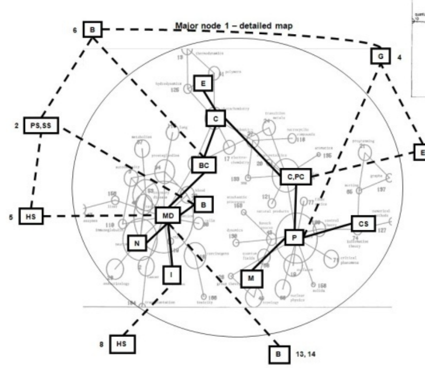
Balaban, A.T., & Klein, D.J. (2006). Is chemistry 'The Central Science'? How are different sciences related? Co-citations, reductionism, emergence, and posets. Scientometrics, *69(3), 615-637.*

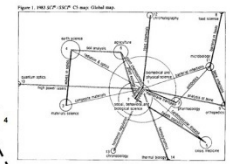
SMALL74 2 – Coding



Griffith, B.C., Small, H.G., Stonehill, J.A., & Dey, S. (1974). Structure of scientific literatures. 2. Toward a macrostructure and microstructure for science. Science Studies, *4(4), 339-365.*

SMALL85 2 – Coding



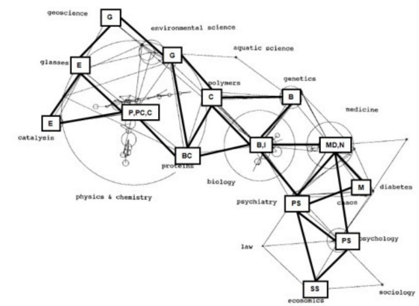


Coding of edges from the nodes in the global map to specific nodes in the NODE1 map were done using the edge labels in the global map.

Dashed edges indicate edges from nodes in the global map to nodes in the NODE1 detail.

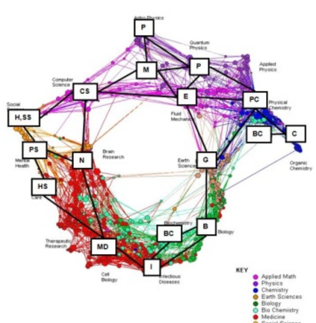
Small, H., & Garfield, E. (1985). The geography of science: Disciplinary and national mappings. Journal of Information Science, *11, 147-159.*

SMALL99 2 – Coding



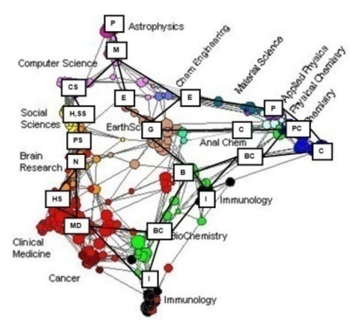
Small, H. (1999). Visualizing science by citation mapping. Journal of the American Society for Information Science, *50(9), 799-813.*

KB-PARA 2 – Coding



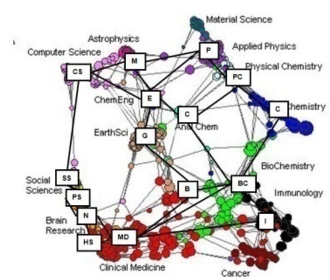
Klavans, R., & Boyack, K.W. (2008). Thought leadership: A new indicator for national and institutional comparison. To appear in Scientometrics, *75(2).*

KB06-TS 2 – Coding



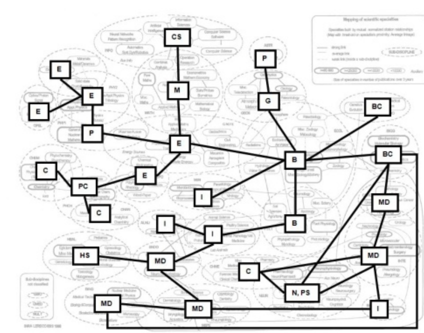
Klavans, R., & Boyack, K.W. (2007). Is there a convergent structure of science? A comparison of maps using the ISI and Scopus databases. In D. Torres-Salinas & H. Moed (Eds.), 11th International Conference of the International Society for Scientometrics and Informetrics (pp. 437-448). Madrid, Spain, June 2007: ISSI.

KB06-SC 2 – Coding



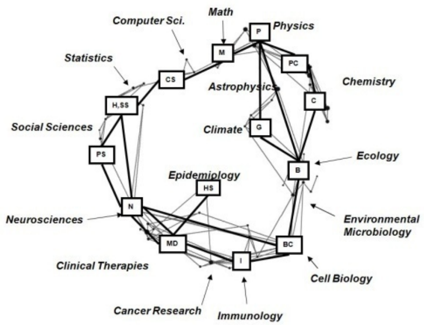
Klavans, R., & Boyack, K.W. (2007). Is there a convergent structure of science? A comparison of maps using the ISI and Scopus databases. In D. Torres-Salinas & H. Moed (Eds.), 11th International Conference of the International Society for Scientometrics and Informetrics (pp. 437-448). Madrid, Spain, June 2007: ISSI.

B-Z 2 – Coding



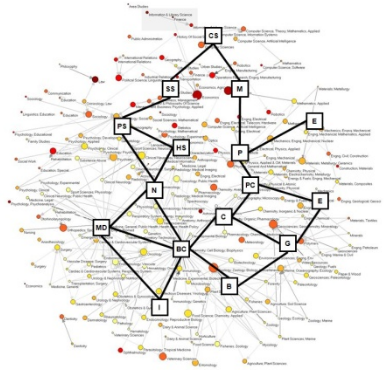
Bassecoulard, E., & Zitt, M. (1999). Indicators in a research institute: A multi-level classification of journals. Scientometrics, *44(3), 323-345.*

K02 2 – Coding



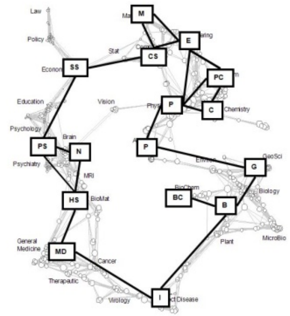
Klavans, R. (2003). Poster at the Sackler Colloquium on Mapping Knowledge Domains, Irvine, CA, May 9-11, 2003.

BACKBONE 2 – Coding



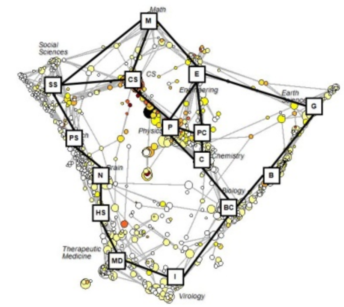
Boyack, K.W., Klavans, R., & Börner, K. (2005). Mapping the backbone of science. Scientometrics, *64(3), 351-374.*

BBK02-S 2 – Coding



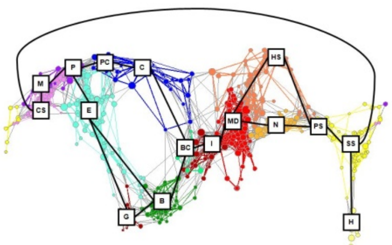
Boyack, K.W., Börner, K., & Klavans, R. (2008). Mapping the structure and evolution of chemistry research. Scientometrics, accepted. OR related conference paper: In D. Torres-Salinas & H. Moed (Eds.), 11th International Conference of the International Society for Scientometrics and Informetrics (pp. 112-123). Madrid, Spain.

B03-ST 2 – Coding



Boyack, K.W. (2008). Using detailed maps of science to identify potential collaborations. Scientometrics, accepted. OR related conference paper: In D. Torres-Salinas & H. Moed (Eds.), 11th International Conference of the International Society for Scientometrics and Informetrics (pp. 124-135). Madrid, Spain.

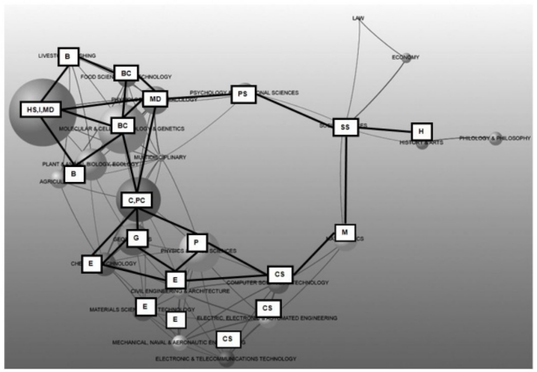
UCSD 2 – Coding



Note: this is the Mercator projection of a map that was originally on a sphere. The visual break between SS and CS was necessitated by use of the Mercator projection. There is an edge between CS and SS.

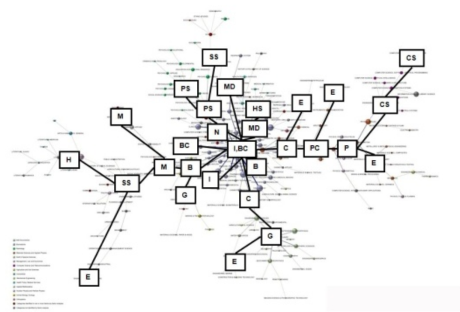
Klavans, R., Patek, M.D., & Boyack, K.W. (2007). Maps of Science: Forecasting Large Trends in Science: Places & Spaces (http://www.scimaps.org/dev/map_detail.php?map_id=164). Detail on this map is also available at www.mapofscience.com.

SCImago-I 2 – Coding



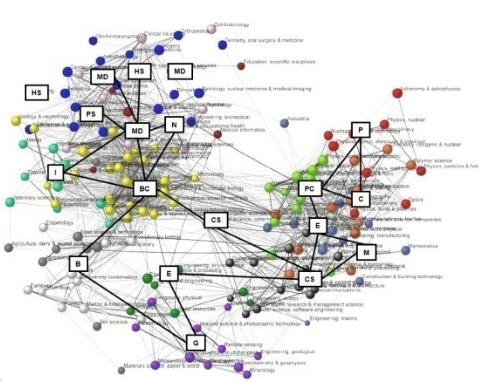
Moya-Anegón, F., Vargas-Quesada, B., Herrero-Solana, V., Chinchilla-Rodriguez, Z., Corera-Álvarez, E., & Munoz-Fernández, F.J. (2004). A new technique for building maps of large scientific domains based on the cocitation of classes and categories. Scientometrics, *61(1), 129-145.*

SCImago-II 2 – Coding



Moya-Anegón, F., Vargas-Quesada, B., Chinchilla-Rodriguez, Z., Corera-Álvarez, E., Munoz-Fernández, F.J., & Herrero-Solana, V. (2007). Visualizing the marrow of science. Journal of the American Society for Information Science and Technology, 58(14), 2167-2179.

L-R 2 – Coding

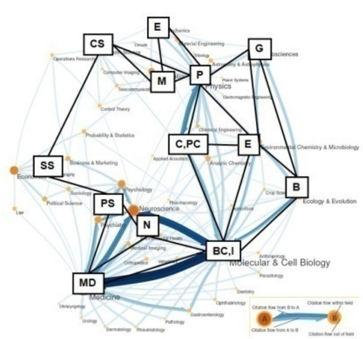


L-R Factor Analysis Categories

Yellow – Biomed – B,BC
Orange – Chemistry – C,CP
Red – Physics – P
Black – CS
Light blue – Engineering – E
Lime – Materials – E
Green – Env sciences – G
Purple – Geology – G
White – Ecology – G
Gray – Agriculture – B
Pink – Neuroscience – N
Teal – Inf Diseases – ID
Brick – General Med – MD
Blue – Clinical Med – MD

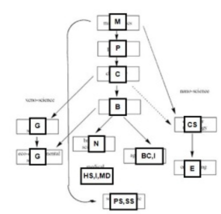
Leydesdorff, L., & Rafols, I. (2007). A global map of science based on the ISI subject categories, from http://users.fmg.uva.nl/lleydesdorff/map06/texts/index.htm

ROSVALL 2 – Coding



Rosvall, M., & Bergstrom, C.T. (2007). Maps of information flow reveal community structure in complex networks. arXiv:0707.0609v1 [phys.soc-ph].

BALABAN-II 2 – Coding

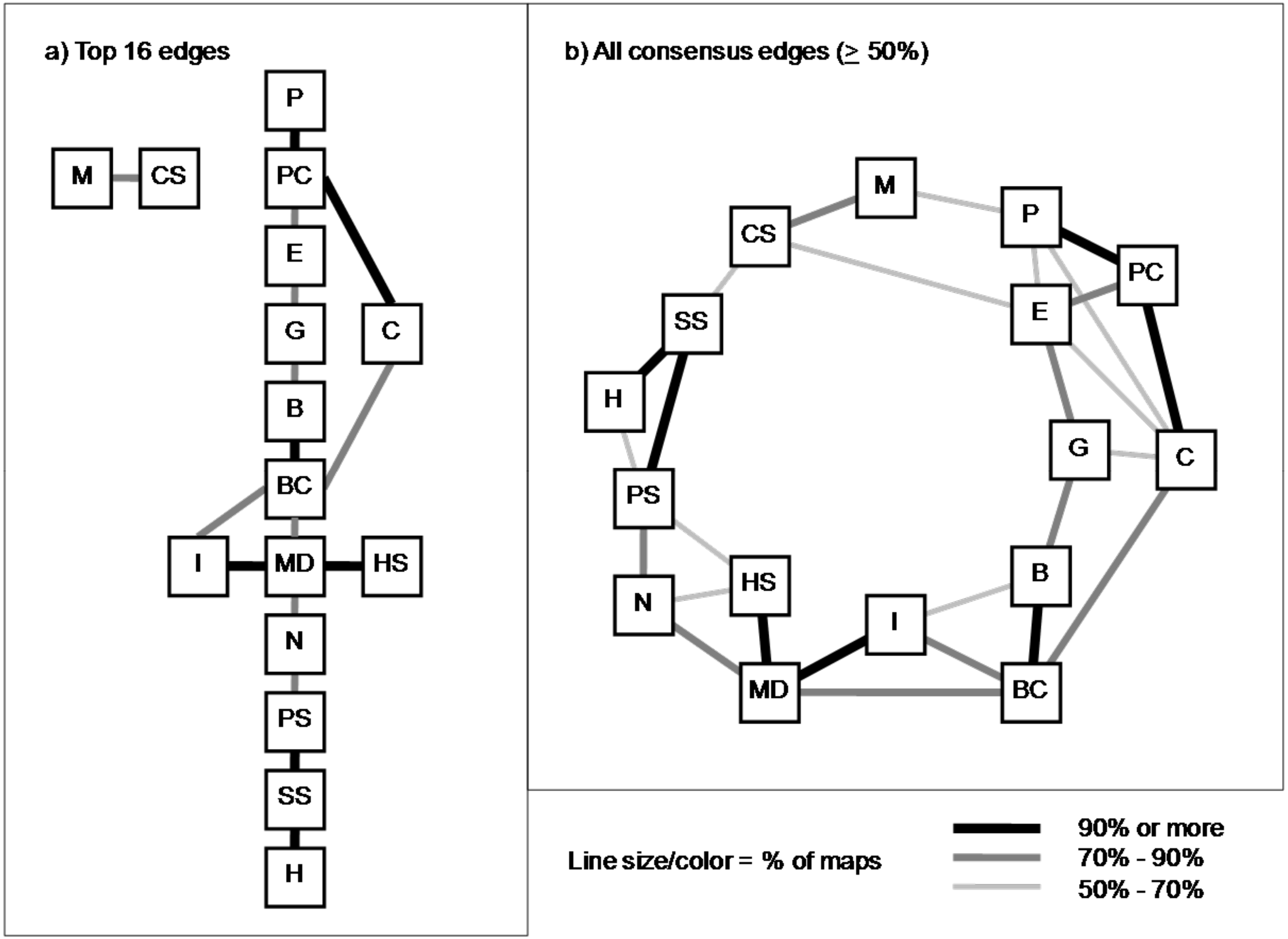


Balaban, A.T., & Klein, D.J. (2006). Is chemistry 'The Central Science'? How are different sciences related? Co-citations, reductionism, emergence, and posets. Scientometrics, *69(3), 615-637.*

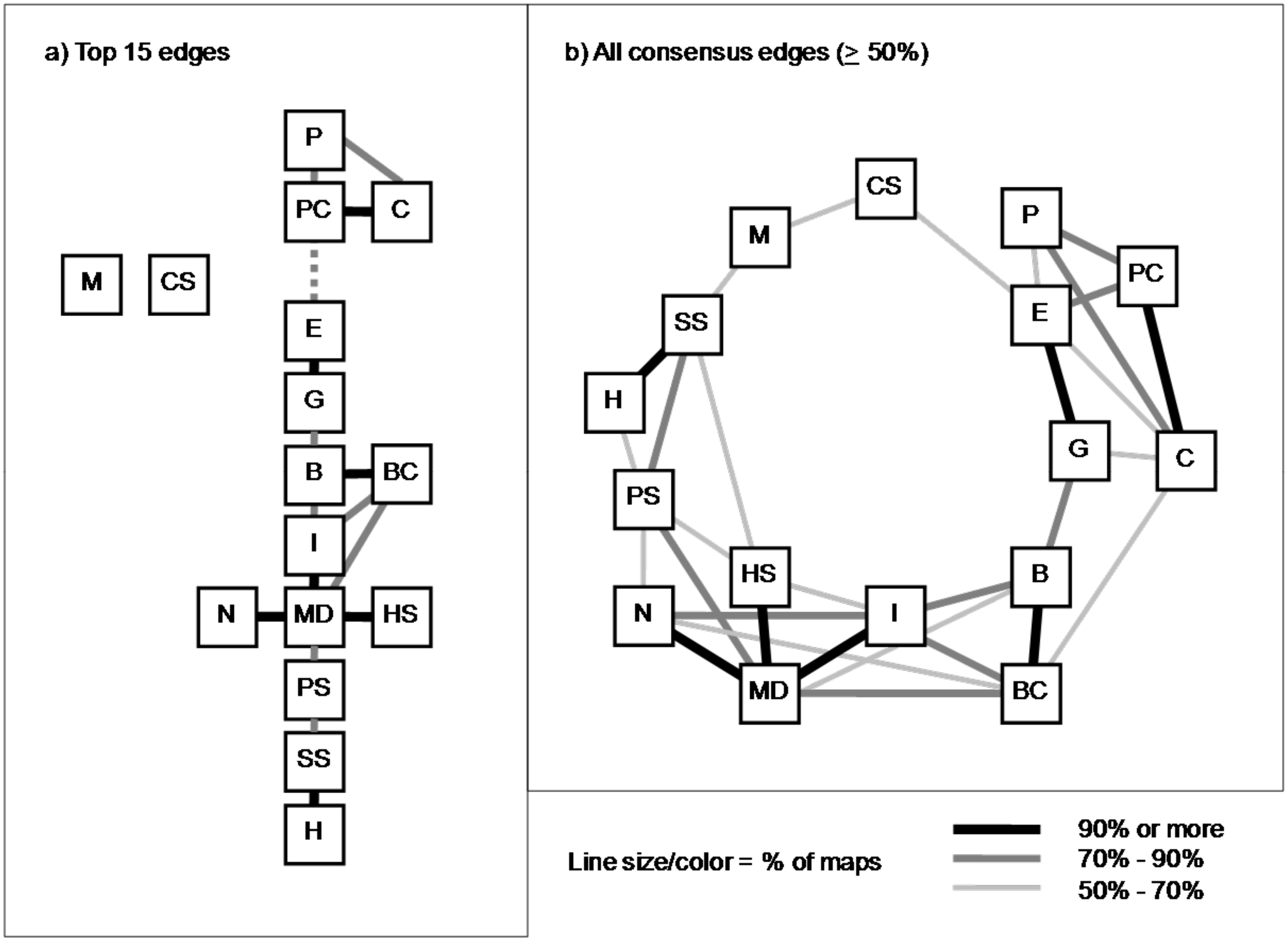
Consensus pairs

Rank	Pair	N	N-poss	%		Rank	Pair	N	N-poss	%
1	B-BC	20	20	100.0		15	BC-MD	14	20	70.0
2	I-MD	20	20	100.0		16	BC-C	14	20	70.0
3	H-SS	8	8	100.0		17	E-P	12	18	66.7
4	C-PC	19	20	95.0		18	B-I	13	20	65.0
5	HS-MD	16	17	94.1		19	CS-SS	10	16	62.5
6	PS-SS	16	17	94.1		20	H-PS	5	8	62.5
7	P-PC	18	20	90.0		21	M-P	11	19	57.9
8	MD-N	16	18	88.9		22	C-E	10	18	55.6
9	E-G	16	18	88.9		23	C-P	11	20	55.0
10	B-G	17	20	85.0		24	HS-N	8	15	53.3
11	BC-I	16	20	80.0		25	CS-E	9	17	52.9
12	E-PC	14	18	77.8		26	C-G	10	20	50.0
13	N-PS	14	18	77.8		27	HS-PS	8	16	50.0
14	CS-M	13	18	72.2						

Consensus map



Consensus map (w/o KBB maps)



Consensus map

- Map is NON-CENTRIC – if all consensus (>50% edges) are used
- Map is HIERARCHICAL – if only top 15/16 edges used

20 maps on the consensus map

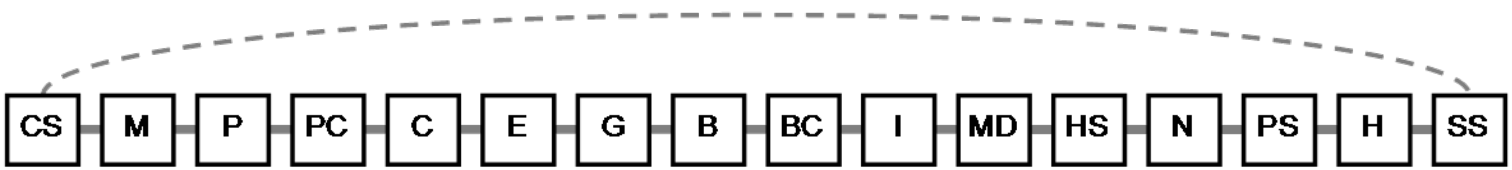
Number of hops	Count	Percent	Accuracy value
1	345	78.4	1.0
2	73	16.6	0.5
3	18	4.1	0
4	4	0.9	0
Total	440	100	0.867

Accuracies of 20 maps

Source map	Year	Type	Local Acc Type1	Local Acc Type2	Regional Acc	Figure of Merit	# Areas	Multi-nodes
KB06-SC	2006	Paper	95.8	94.0	100.0	96.6	15	0
Backbone	2004	Jnl	97.6	88.0	100.0	95.2	15	0
UCSD	2007	Jnl	95.7	88.9	100.0	94.8	16	0
Ellingham	1948	Expert	90.0	92.1	100.0	94.0	12	1
KB-Para	2005	Paper	92.3	94.4	93.8	93.5	16	1
Bernal	1939	Expert	85.7	94.0	100.0	93.2	15	2
Scimago-I	2004	Categ	90.9	87.5	100.0	92.8	15	2
KB06-TS	2006	Paper	91.7	90.7	93.8	92.1	16	1
B03-ST	2005	Jnl	92.5	82.0	100.0	91.5	15	0
BBK02-S	2004	Jnl	92.5	80.0	100.0	90.8	15	0
Rosvall	2007	Jnl	78.3	93.2	100.0	90.5	14	2
Small99	1999	Paper	78.6	89.5	100.0	89.3	13	3
Balaban-II	2007	Pre-req	85.0	82.0	100.0	89.0	15	4
K02	2002	Jnl	84.2	81.8	100.0	88.7	15	1
L-R	2007	Categ	86.1	73.9	100.0	86.7	14	0
Balaban-I	2007	Expert	73.9	79.6	100.0	84.5	16	3
Small85	1985	Paper	84.2	76.0	86.7	82.3	15	2
Small74	1974	Paper	69.2	76.5	100.0	81.9	13	2
B-Z	1999	Jnl	80.6	71.7	93.3	81.9	14	1
Scimago-II	2007	Categ	90.0	75.9	75.0	80.3	16	1

Reasons to favor NON-CENTRIC

- Riemannian (curved) space is inherently more accurate than Euclidean (x,y,z) space



- Hierarchy and centric maps both imply favored status
- Non-centric maps
  - Do not impose artificial boundaries
  - Can show interdisciplinarity and new discoveries in an exciting way

Consensus map summary

- Consensus map generated from 20 maps
  - Robust
  - NON-CENTRIC map if all consensus edges are used
- Simplified map (circular) may be an effective map for policy purposes
  - Show interdisciplinary
  - Show technology (patent) profiles
  - Etc.

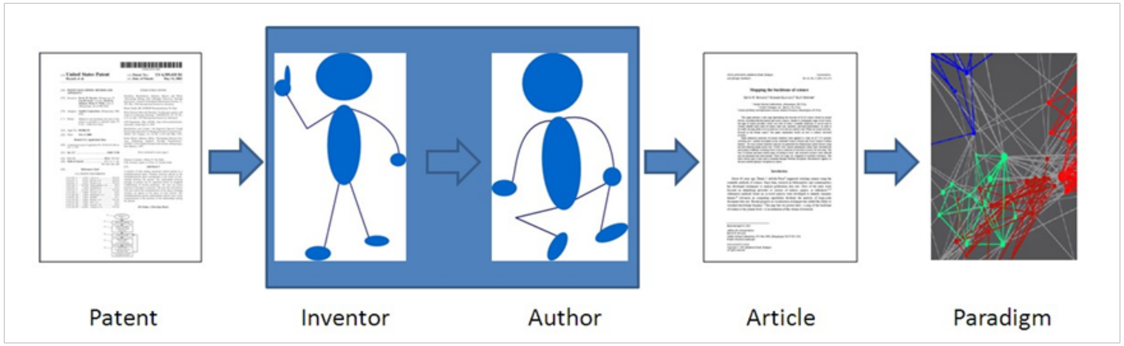
Science / technology interaction

Linking patents to articles

- Variety of methods possible
  - Text (titles, abstracts, etc.)
    - Patent abstracts tend to have different language than article abstracts
  - Non-patent references
    - Roughly 2/3 are to articles/proceedings papers
    - Data cleaning is an issue; no standard format
  - Inventor-authors
    - Name disambiguation is an issue
    - Relatively small overlap between authors / inventors

We use inventor-authors

- Data: Scopus papers, USPTO patents, 2002-2006
- To circumvent the name disambiguation issue we focus on uncommon names



- Assumes that patents belong to the same discipline or paradigm as the papers
  - Both come from the same intellectual space (the inventor-author's output)

Method

Articles

- Author-Org pairs for all papers 2002-2006
- Find fraction of author for each Author-Org pair
- Limit set to those with frac>0.5 (assures each name appears only once)

Patents

- Inventor-Assg pairs for all patents 2002-2006
- Find fraction of inventor for each Inv-Assg pair
- Limit set to those with frac>0.5

- Join data using Auth=Inv
- Check Org=Assg to assure match

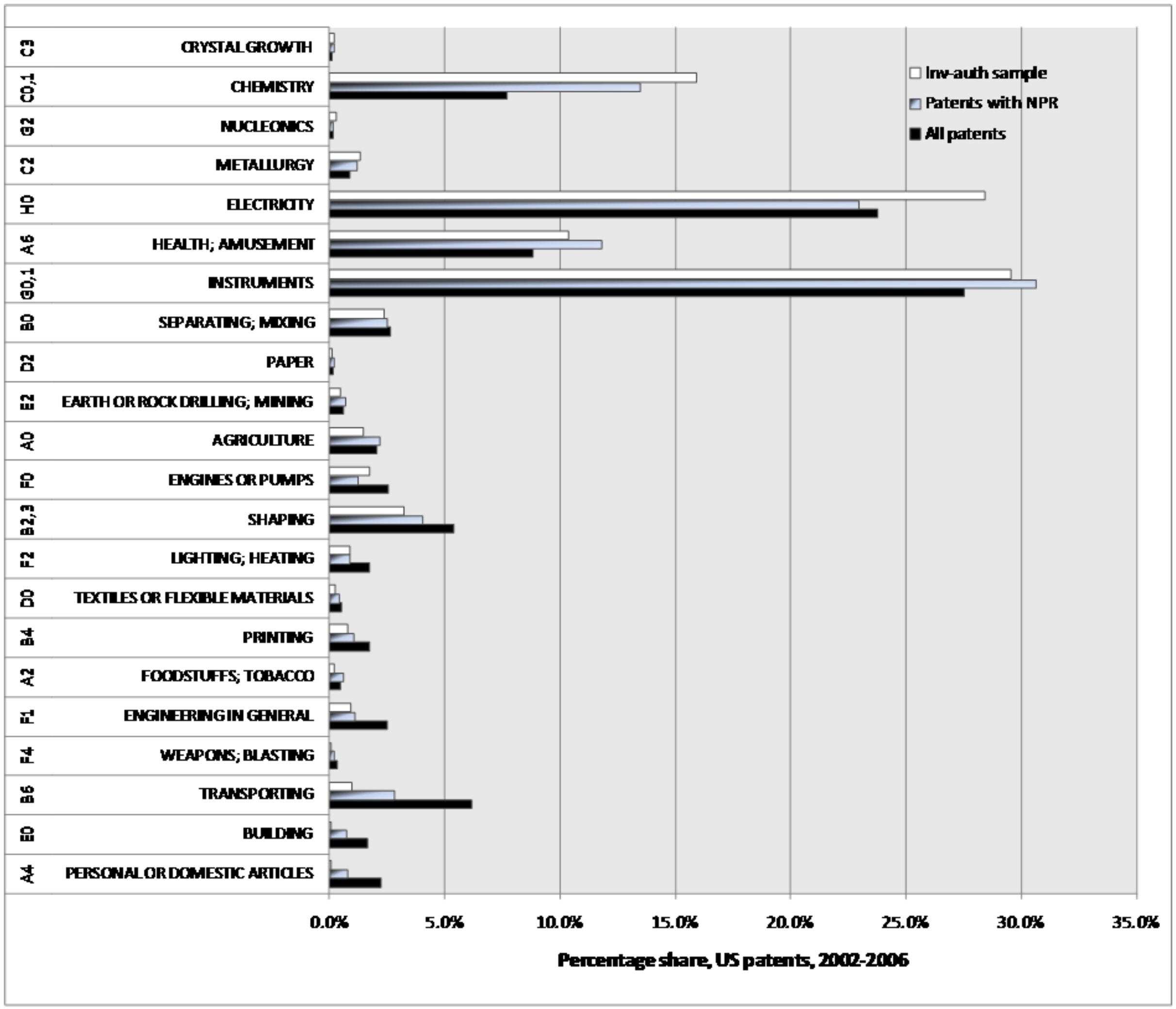
Data

Rareness fraction range	# auth names	# inv names	Inv-auth matches	Inv-auth + inst matches	Fraction valid matches	# patents	NULL assignees
f = 1.00	1,106,404	278,146	35,360	7,843	0.222	18,816	3,708
1.0 ≥ f ≥ 0.9	1,138,340	281,214	38,842	9,068	0.233	25,370	3,973
1.0 ≥ f ≥ 0.8	1,222,530	292,594	47,454	11,362	0.239	34,653	4,653
1.0 ≥ f ≥ 0.7	1,305,848	304,527	56,774	13,440	0.237	42,129	5,391
1.0 ≥ f ≥ 0.6	1,462,269	330,886	76,027	17,077	0.225	52,106	6,948
1.0 ≥ f > 0.5	1,512,207	335,987	84,402	18,251	0.216	55,820	7,703
1.0 ≥ f ≥ 0.5	1,971,180	425,546	148,532				
UNIQUE (authfi)	2,182,303	436,521					
UNIQUE (authfi+inst)	8,712,536	1,049,650					

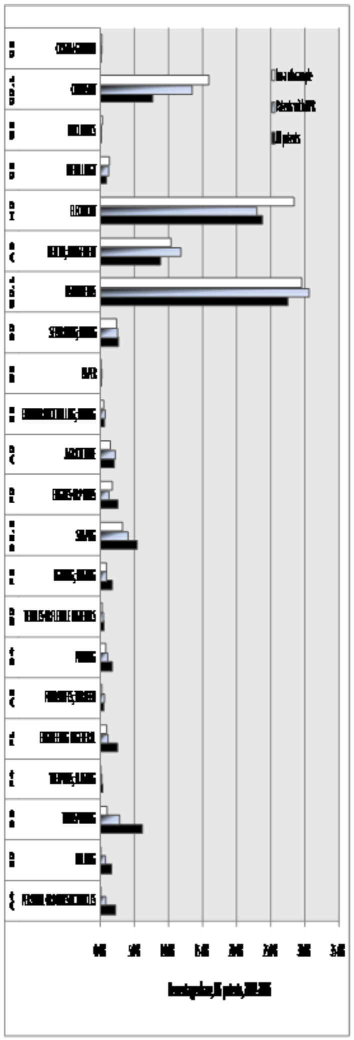
Validated institutional matches

- 84,402 potential matches (rare author name matches) were manually inspected. 18,251 of these matches had an institutional match as well
- 55,387 patents (6.7% of US patents over the time frame) were invented by these matched authors
  - Patents were fractionally assigned to disciplines and paradigms through the “patent-inventor/author-paper-paradigm” linkage chain
  - 132,600 papers were authored by these 18,251 inventor-authors

Patent IPC distribution

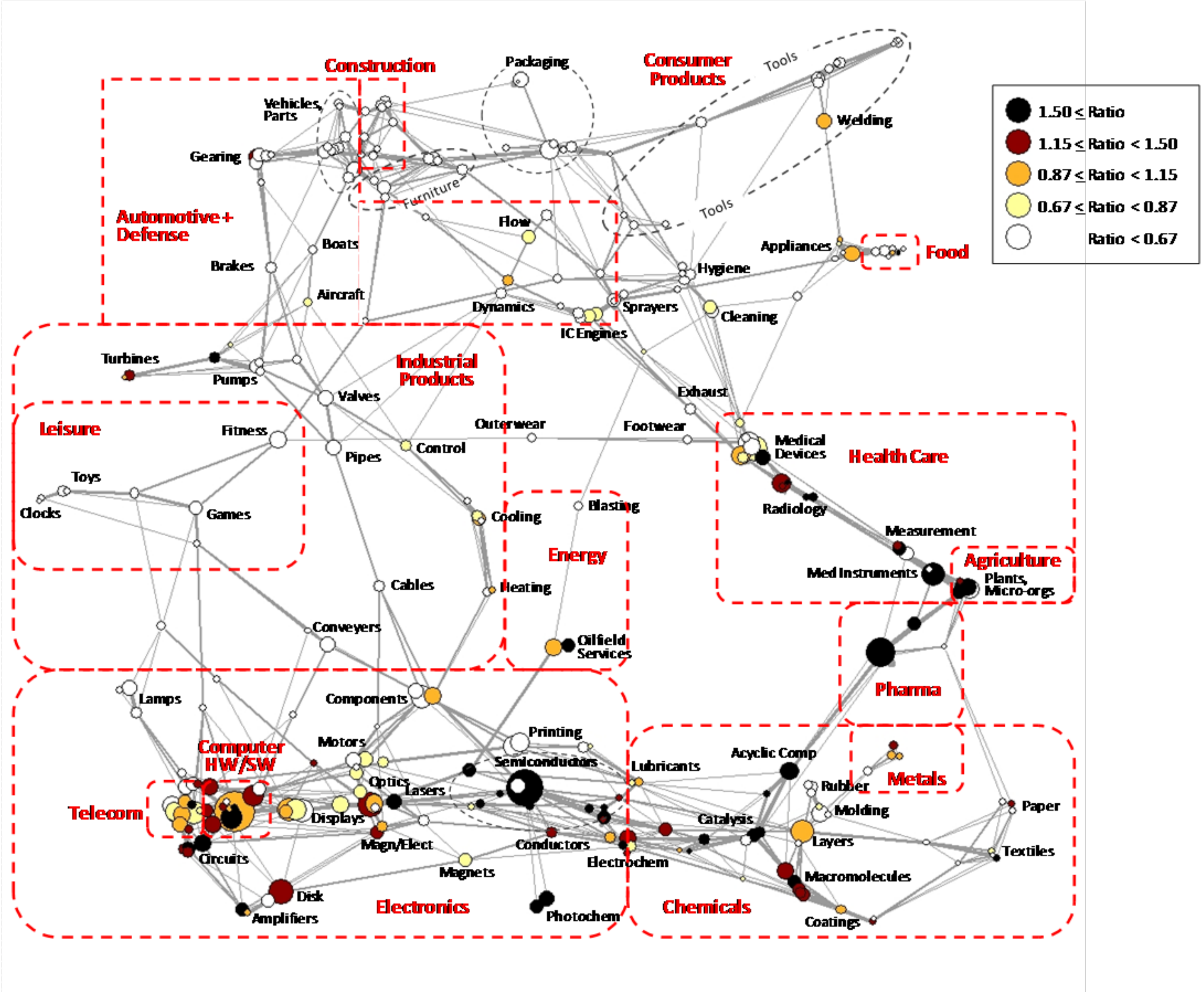


Patent IPC Distribution



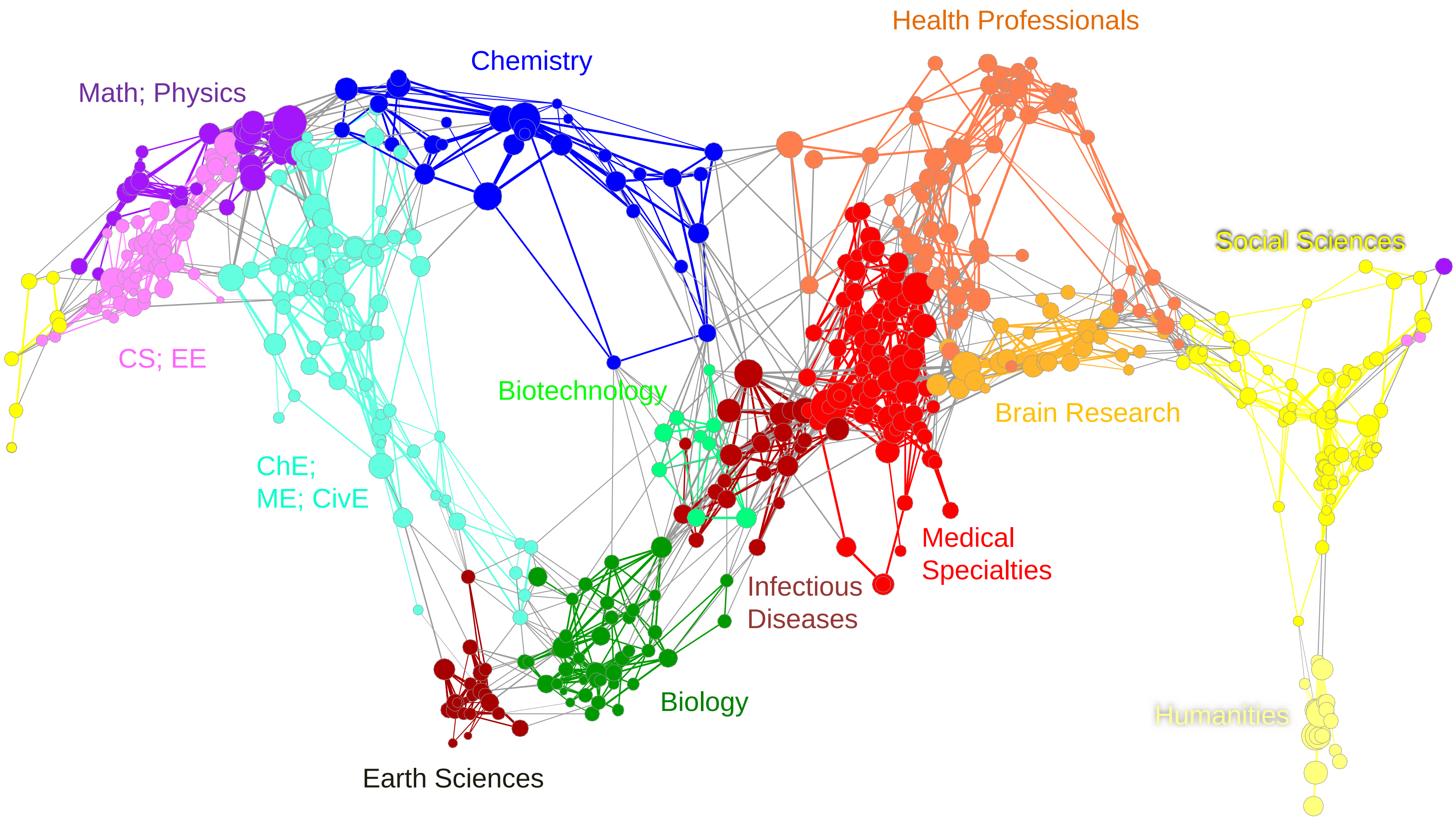
- Sample is not representative of actual distribution by class
- Should it be? - NO
  - Representative distribution assumes that all patents and classes are equally likely to be inherently linked to science
  - We believe this is a faulty assumption
    - Some classes intuitively do not link to science (e.g., A4 – Personal articles, E0 – Building)
    - Others are intuitively science based (e.g. C0 – Chemistry, A6 – Health)
    - Different industries have different publishing habits

Patent map (IPC subclasses – 3 char)

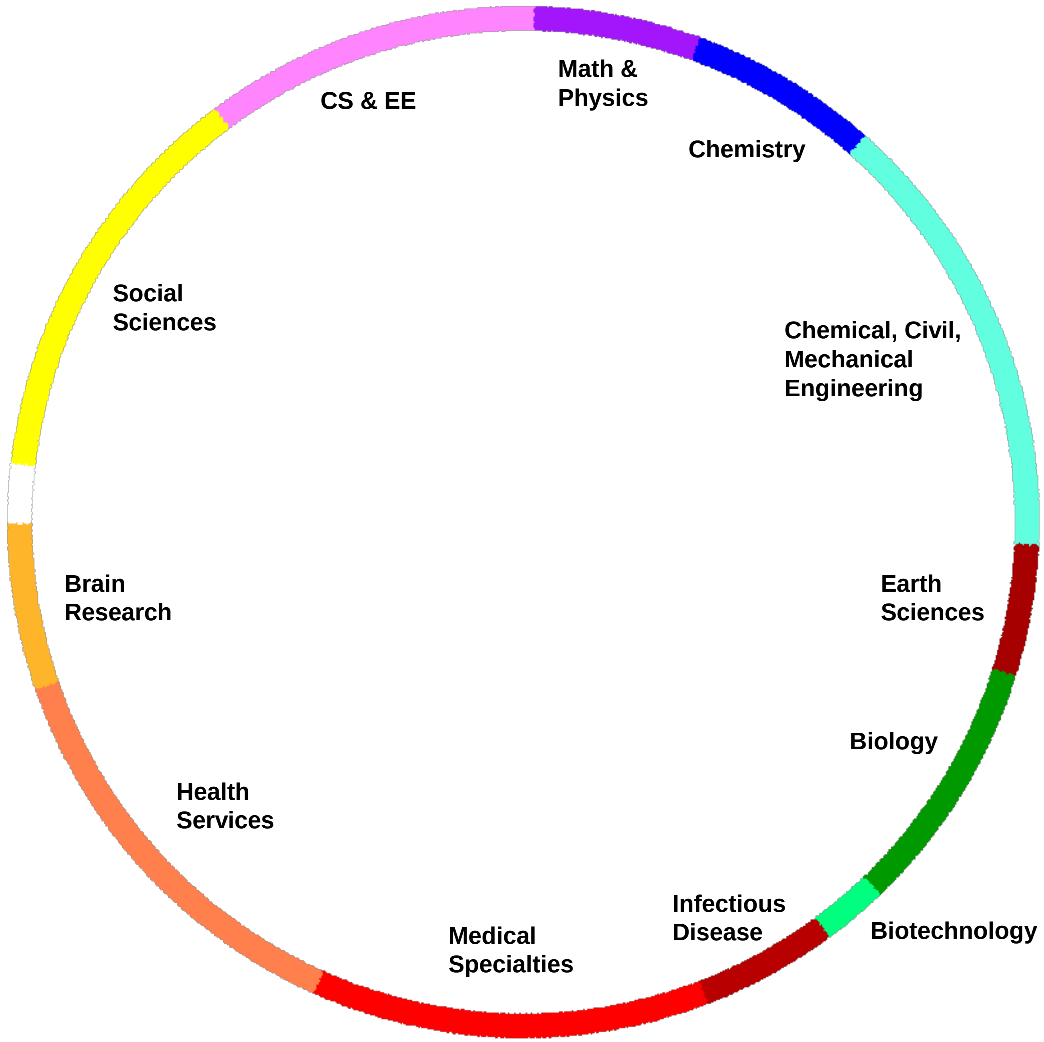


Using maps as templates

Disciplinary map – paper counts



Circle map


CS & EE
Math & Physics
Chemistry
Chemical, Civil, Mechanical Engineering
Earth Sciences
Biology
Biotechnology
Infectious Disease
Medical Specialties
Health Services
Brain Research
Social Sciences

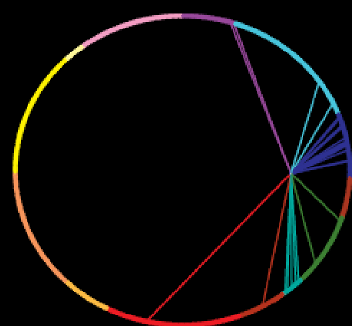
SOCIAL SCIENCE · HUMANITIES · COMPUTER SCIENCE · MATH & PHYSICS · ENGINEERING · CHEMISTRY · EARTH SCIENCES · BIOLOGY · BIOCHEMISTRY · INFECTIOUS DISEASES · MEDICAL SPECIALTIES · BRAIN RESEARCH · HEALTH SERVICES

SEED · *January/February 2008*

DEGREES OF INTEGRATION These diagrams of scientific institutions were constructed by sorting over 16,000 academic journals into 554 different clusters, which were then grouped into 13 major fields. These major fields are shown as the 13 colored arcs comprising each circular map. Arc lengths represent the number of journals in the corresponding fields. These circular maps can be used to display the disciplinary makeup of institutions. Take, for example, the Rensselaer Polytechnic Institute Center for Biotechnology and Interdisciplinary Studies. First, the papers authored by this center are mapped to their corresponding disciplines on the circle. Then the average position of these papers is calculated. Colored rays are drawn from this point (the institutional node) to each of the papers on the circle to show disciplinary makeup. The position of the institutional node and distribution of the colored rays give a measure of the interdisciplinarity of the institution. The closer the institutional node is to the center of the circle, and the greater number of colors it incorporates, the more interdisciplinary the institution.

Allen institute for brain science

Arizona state university biodesign institute

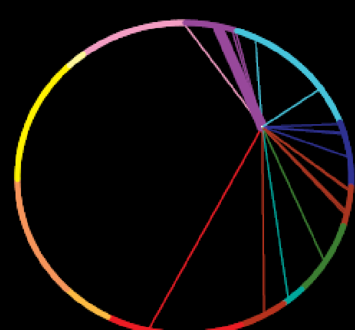


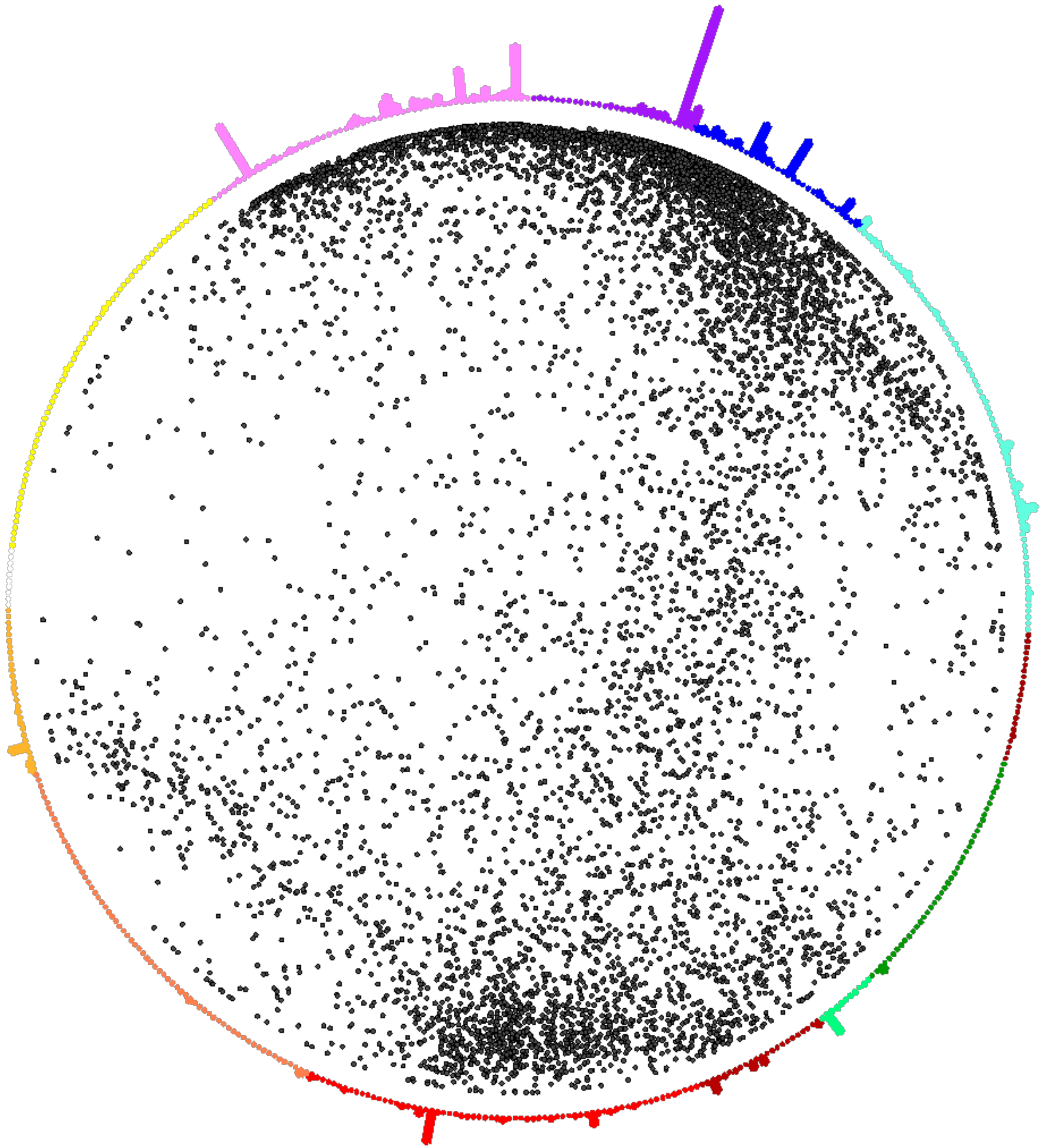
University of british columbia college for interdisciplinary studies

Cornell life sciences initiative

Harvard origins of life initiative

Mit's center for bits and atoms





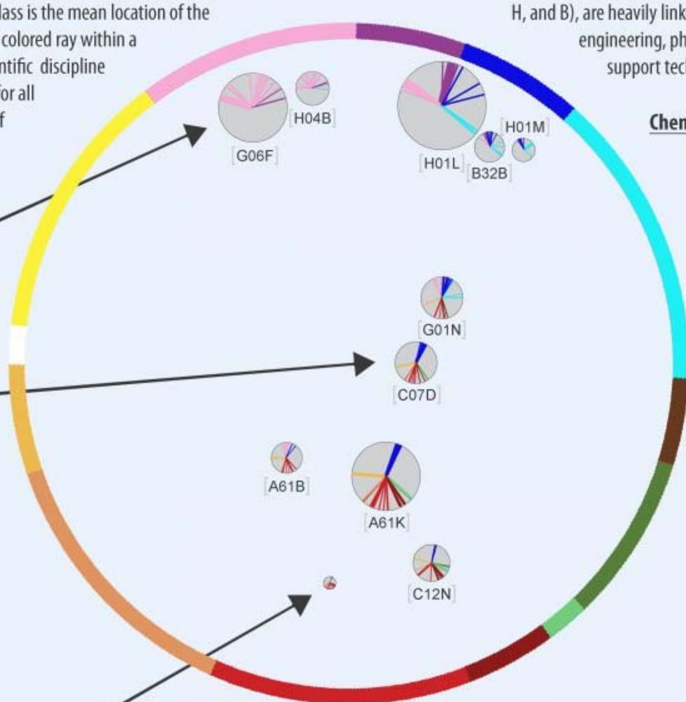
Locating Patents on the Simplified Map of Science

Science-Technology Linkage: Patents were linked to the 554 scientific disciplines on the map of science. These links were based on a set of 18,250 people who were both inventors (on 55,400 patents) and authors (of 132,600 scientific publications) from 2002-2006. Additional information about the method for linking inventors and authors is available in Boyack & Klavans, "Measuring science-technology interaction using rare inventor-author names," Journal of Informetrics, 2008.

Patent Classes: Ten large international patent classes with very strong linkages to science (large numbers of inventor-authors) are represented as circles inside the map of science. The location of each patent class is the mean location of the scientific disciplines it draws upon. Each colored ray within a patent circle points to an associated scientific discipline on the circle of science. Rays are shown for all disciplines contributing to at least 1% of the patents in a class.

For example, class **G06F** (digital data processing) is dominated by relationships to computer science (pink), and is thus very near the upper edge.

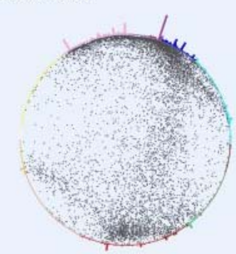
By contrast, class **C07D** (heterocyclic compounds) is linked to disciplines in chemistry (blue) and in the medical and biological sciences (reds and greens), and is thus near the center of the circle of science. Patent circle sizes reflect the relative numbers of US patents per class granted from 2002-2006.

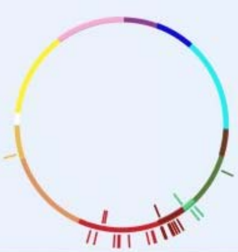


Physics and Computer Science Based Patents: The electronics, hardware & software, and telecommunications industries (represented mainly by international patent classes in sections G, H, and B), are heavily linked to the physical sciences. Computer science, electrical engineering, physics, and chemistry are the core areas of science which support technical progress in the above-named industries.

Chemical & Medical Patents: Patents in chemistry (mainly from classes in section C) and medicine (mainly from classes in section A) do not build exclusively on single areas of science. Rather, patents in these classes tend to build on science from a combination of the chemical and medical areas, and are thus far more interdisciplinary in their science base than are electronics patents.

Gaps: The positions of 20,000 individual patents are shown on the small circle map below. Areas of concentration and areas with few patents can both be seen. The largest gaps at the edges of the circle are adjacent to the social sciences (yellow), earth sciences (brown), and health services (peach). Few patents are associated with scientific advances in these fields.





Shifting Scientific Roots of Stem Cell Technology: The scientific disciplines associated with over 1,800 patents in stem cell technology were examined over time. Four CORE disciplines were found to dominate, accounting for 48% of the patents, and are shown as tic marks on the inside of the small circle map to the left. The next 20 disciplines account for 36% of the patents, are considered PERIPHERAL, and are shown as tic marks on the outside of the small circle map. Over time, there has been a shift from CORE to PERIPHERAL disciplines, as shown below.

KEYS

CORE

PERIPHERAL

Patent Classes: From top left
G06F: Digital data processing
H04B: Transmission
H01L: Semiconductor devices
B32B: Layered products
H01M: Batteries, etc.
G01N: Analyzing material properties
C07D: Heterocyclic compounds
A61K: Medical preparations
C12N: Micro-organisms; enzymes
A61B: Diagnosis; surgery

CS; EE | Math; Physics | Chemistry | Engineering | Earth Sciences | Biology | Biotech | Infect Disease | Med Specialties | Health Services | Brain Research | Humanities | Social Sciences

Places & Spaces
Iteration 4

Summary

- Consensus map generated from 20 maps
  - Robust
  - NON-CENTRIC map if all consensus edges are used
- Simplified map (circular) may be an effective map for policy purposes
  - Show interdisciplinary
  - Show technology (patent) profiles
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