位置与空间: 绘制科学地图

黄维霞
网络与信息可视化研究中心
图书馆和信息科学学院
印第安那大学

May 17th, 2008

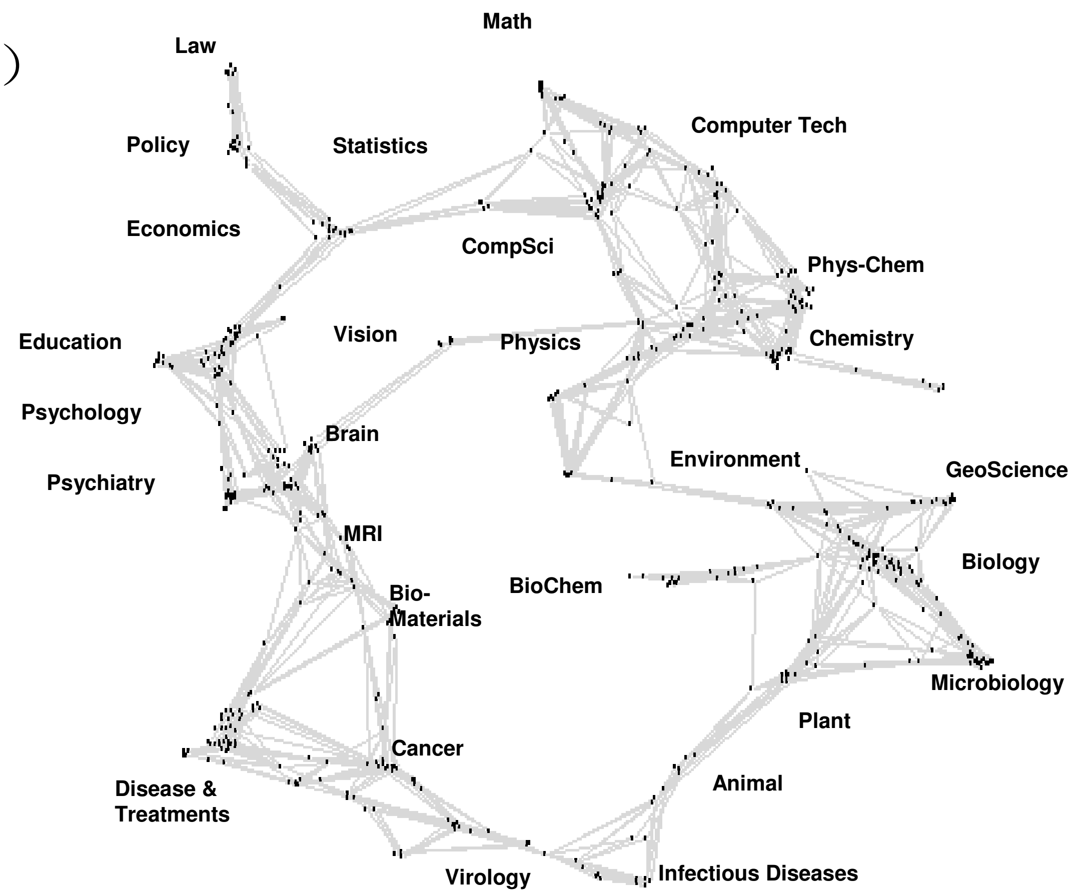
位置与空间: 绘制科学地图

- 什么是科学地图
- 为什么要绘制科学地图
- 科学地图有哪些应用

科学学科分布图

Kevin W. Boyack & Richard Klavans

- 数据来自汤姆森科技2002年科学引文数据库（SCI/SSCI）107万篇论文, 2450万条引文数据, 7,227学术期刊
- 论文通过学术期刊进行聚类
- 学术期刊进行再聚类，形成671个学科子集
- 共引文的次数决定了两点之间的连线的粗细。
- 用VxOrd布局算法得到学科(x,y)坐标。



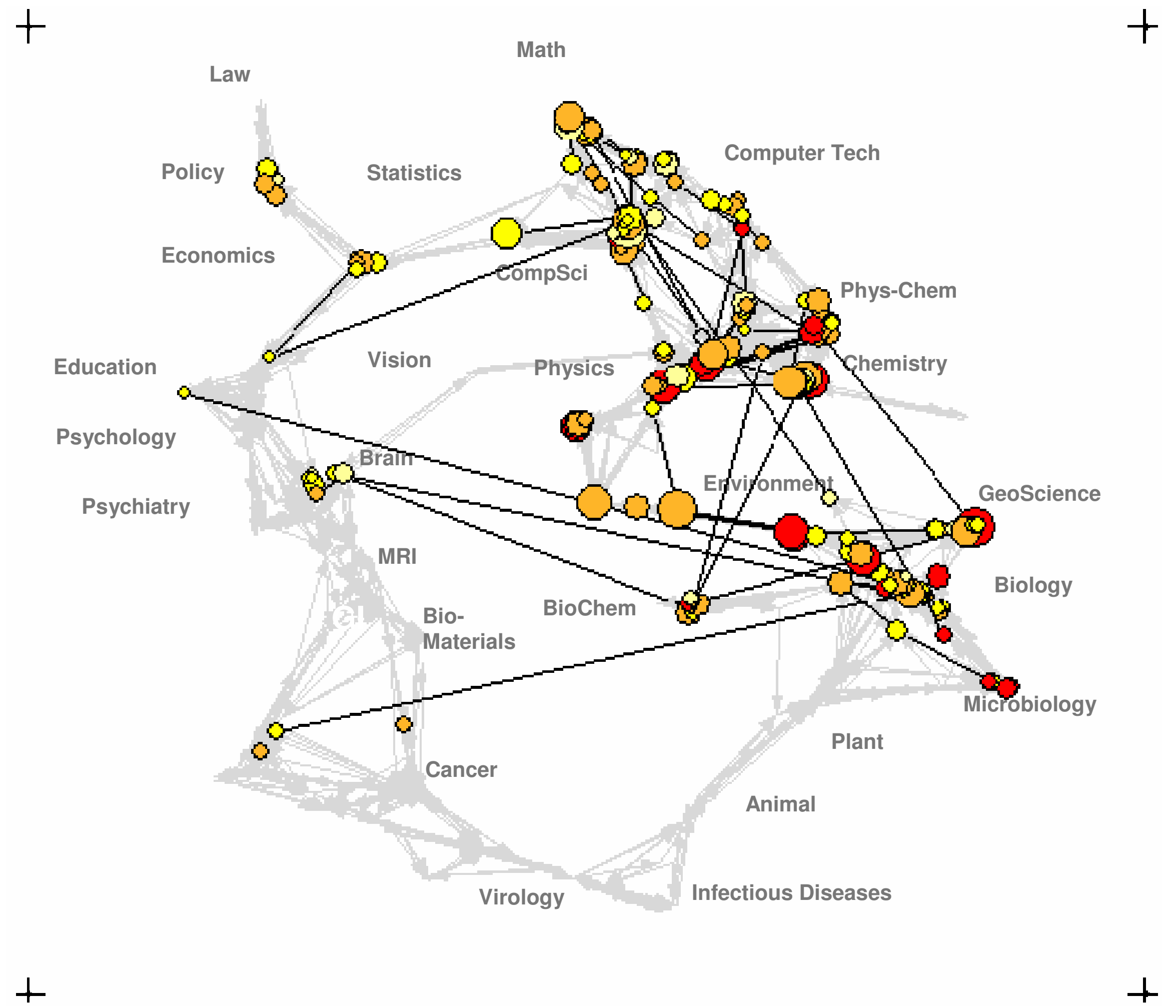
Kevin W. Boyack , katy borner & Richard Klavans. (2007). Mapping the Structure and Evolution of Chemistry Research.

科学地图的应用: **Identifying core competency**

Kevin W. Boyack & Richard Klavans,

美国国家自然科学基金（**NSF**）资助方向

Funding Patterns of the National Science Foundation (NSF)

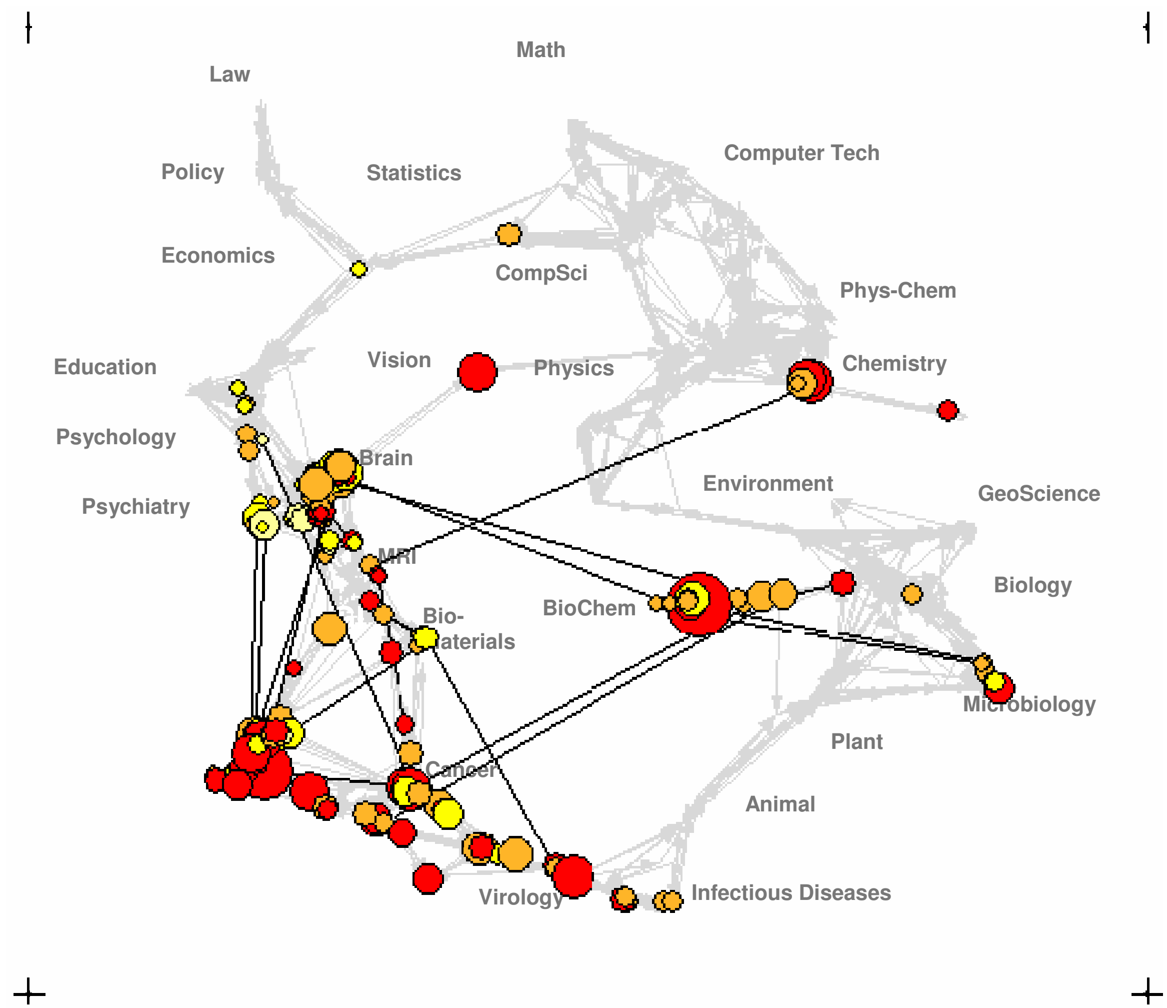


科学地图的应用: Identifying core competency

Kevin W. Boyack & Richard Klavans

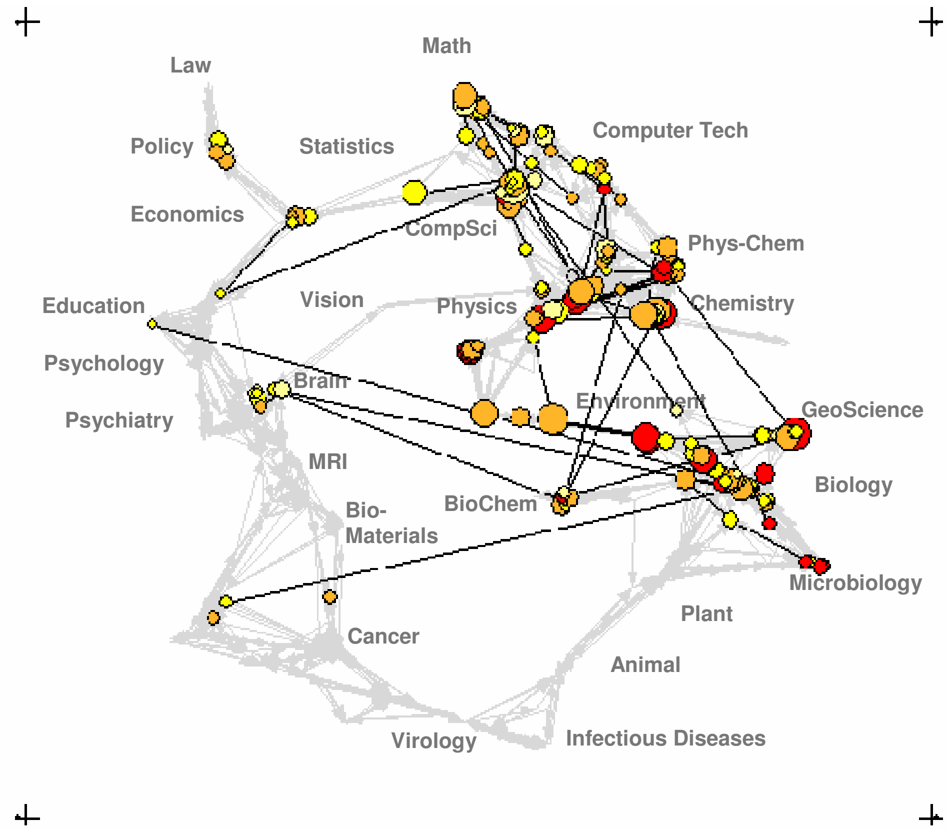
美国NIH基金资助方向

Funding Patterns of the National Institutes of Health (NIH)

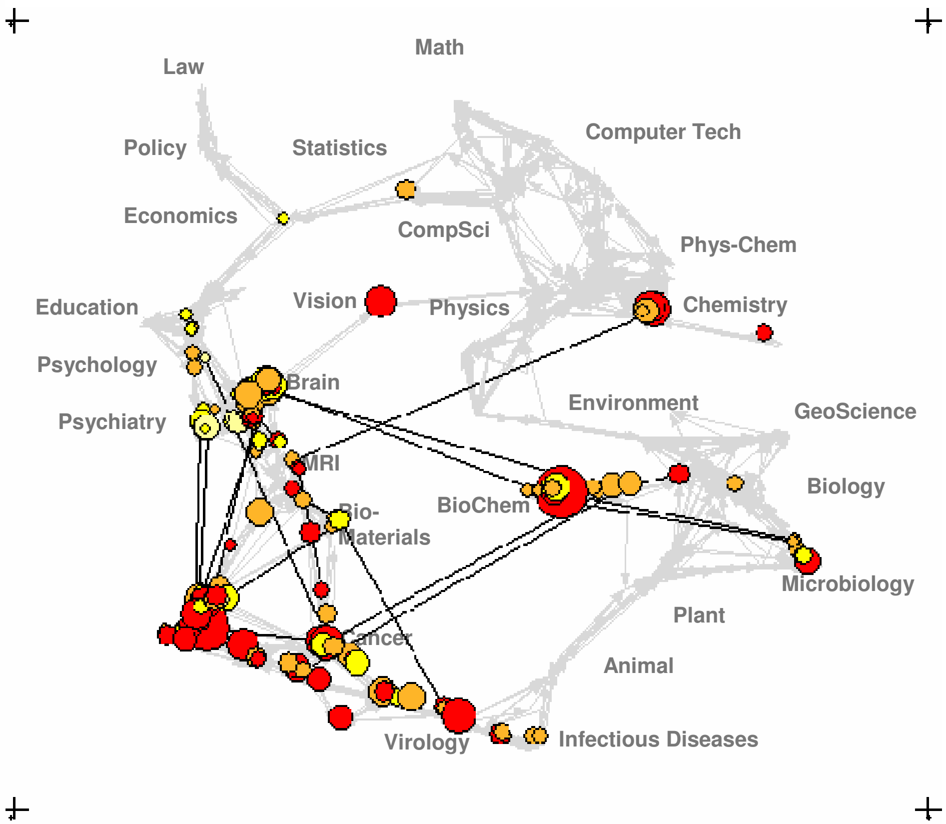


对比 (Compare and Contrast)

美国NSF基金资助方向



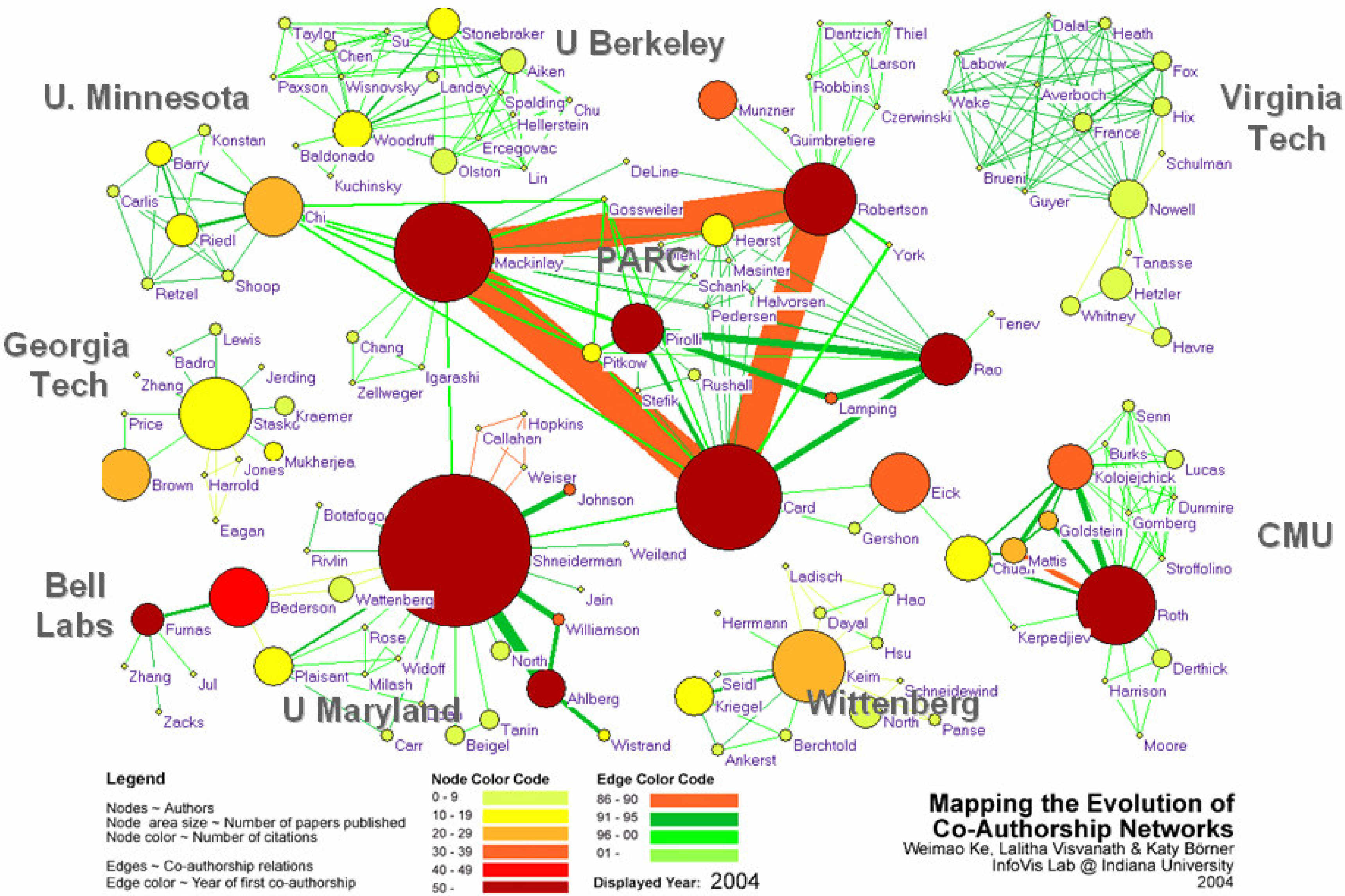
美国NIH基金资助方向



科学地图的应用：

Mapping the Evolution of Co-Authorship Networks

Ke, Visvanath & Börner, (2004) Won 1st price at the IEEE InfoVis Contest



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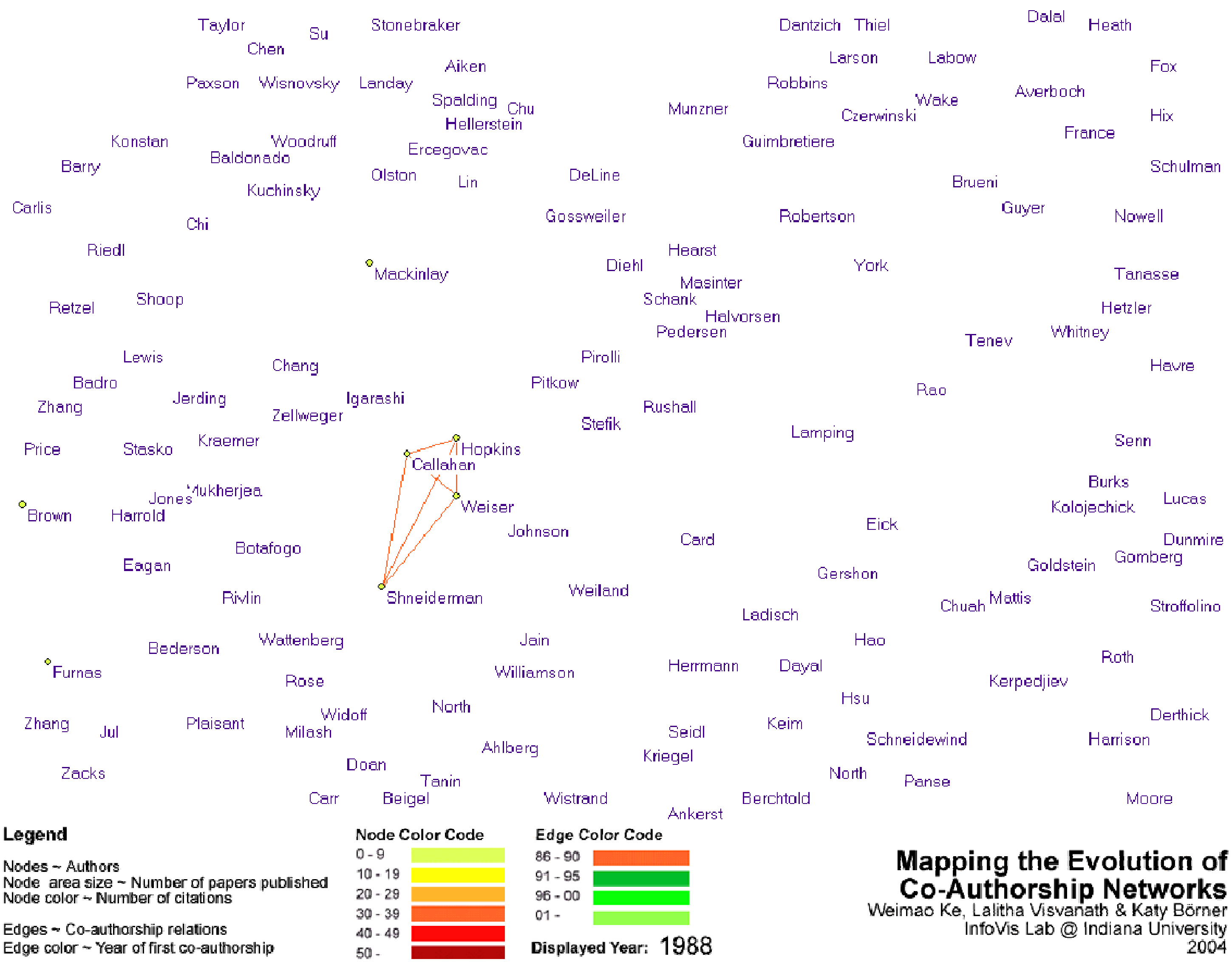

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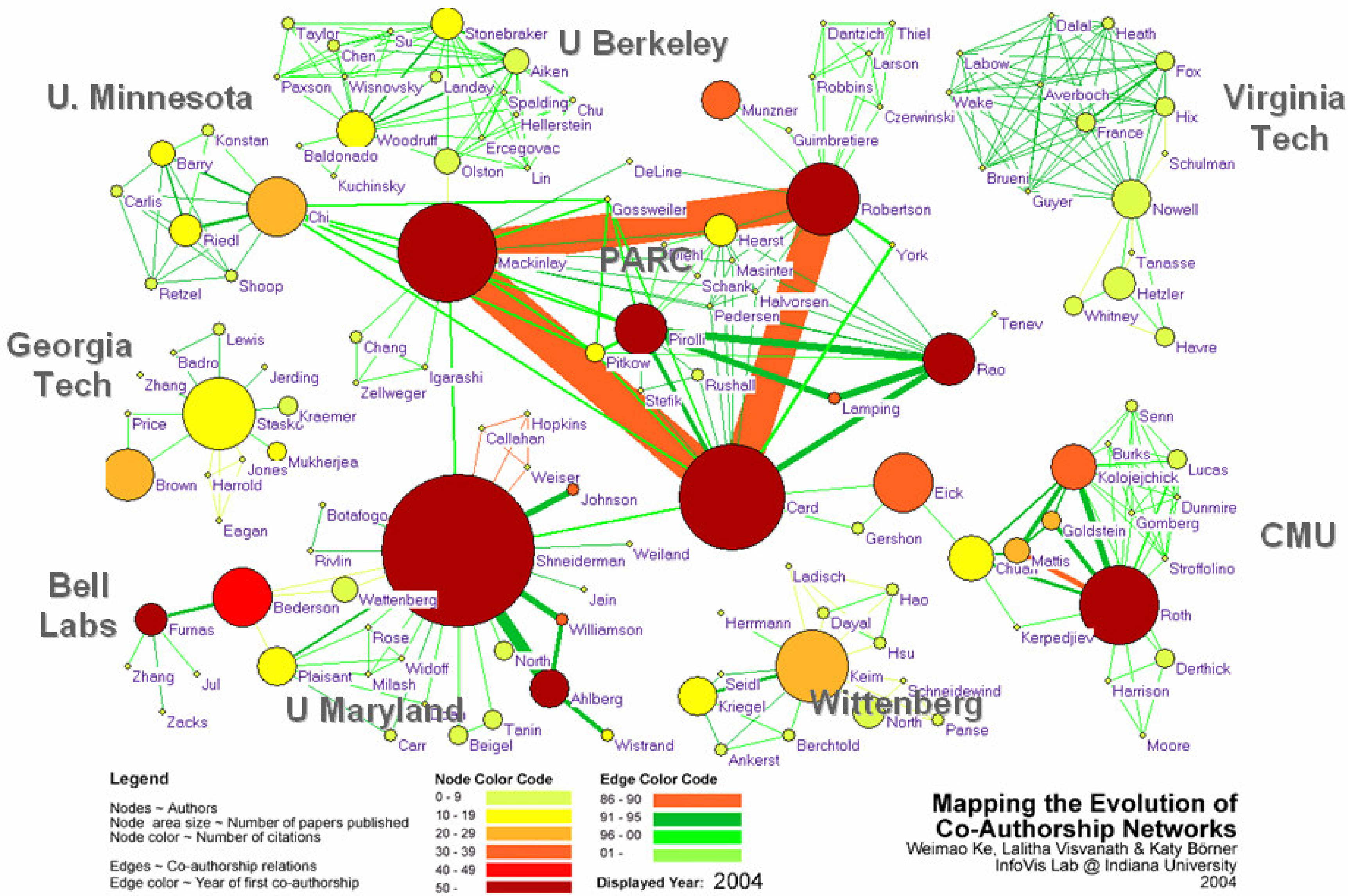
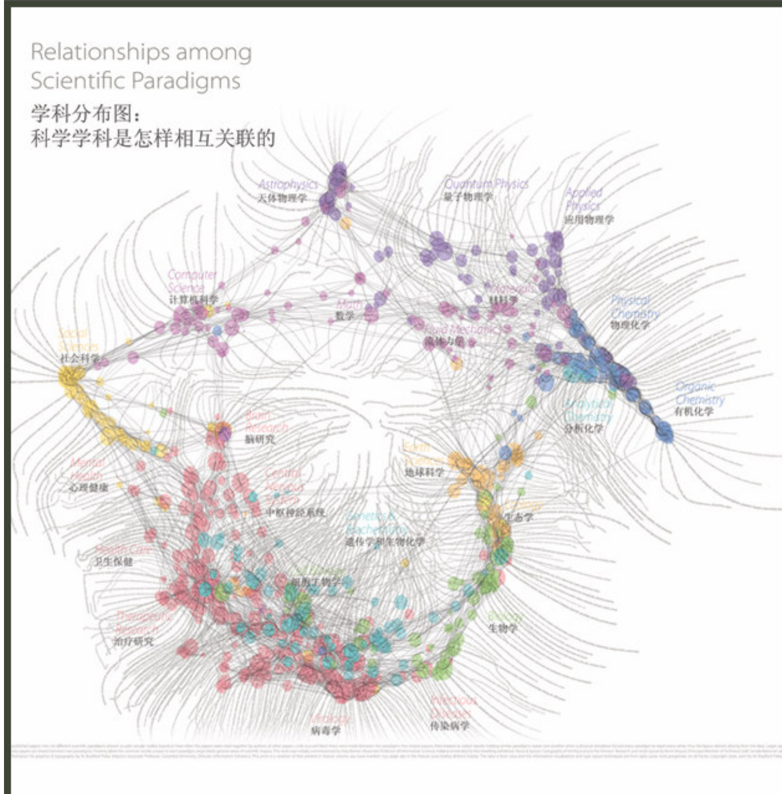
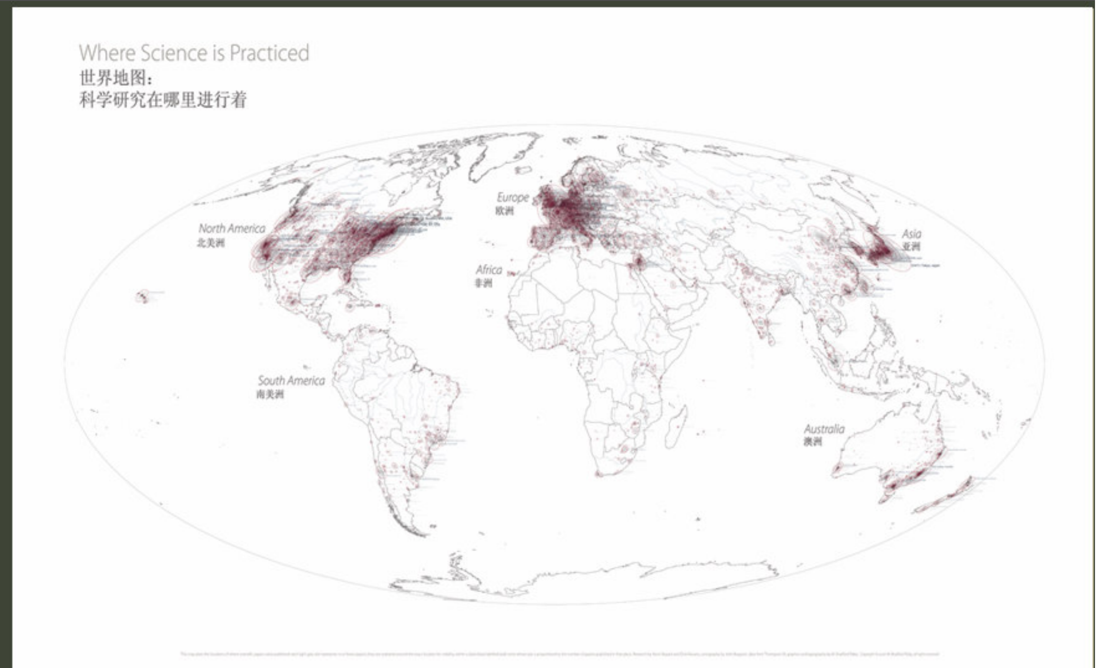


科学地图在教育上的应用：

Coupling Science Map and World Map





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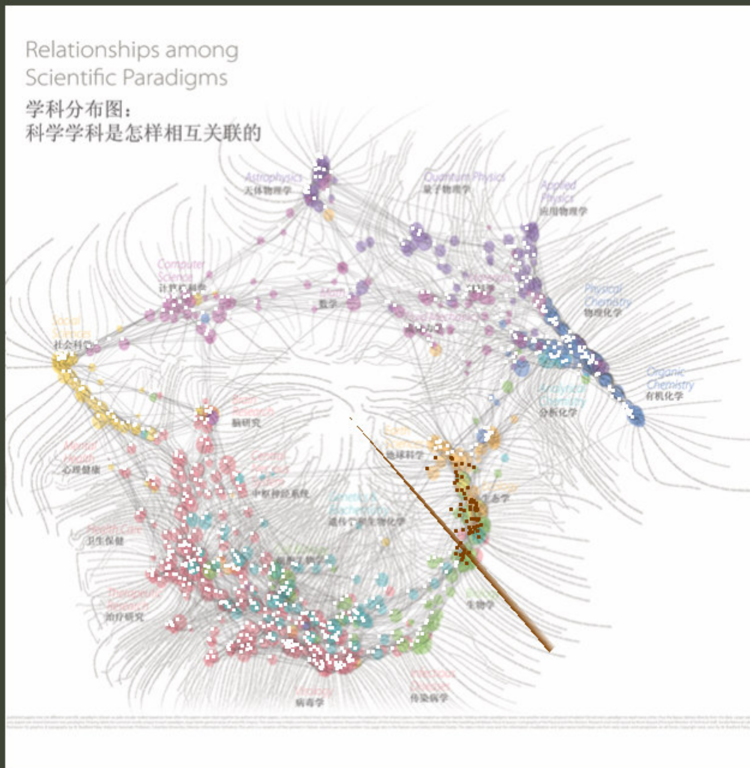
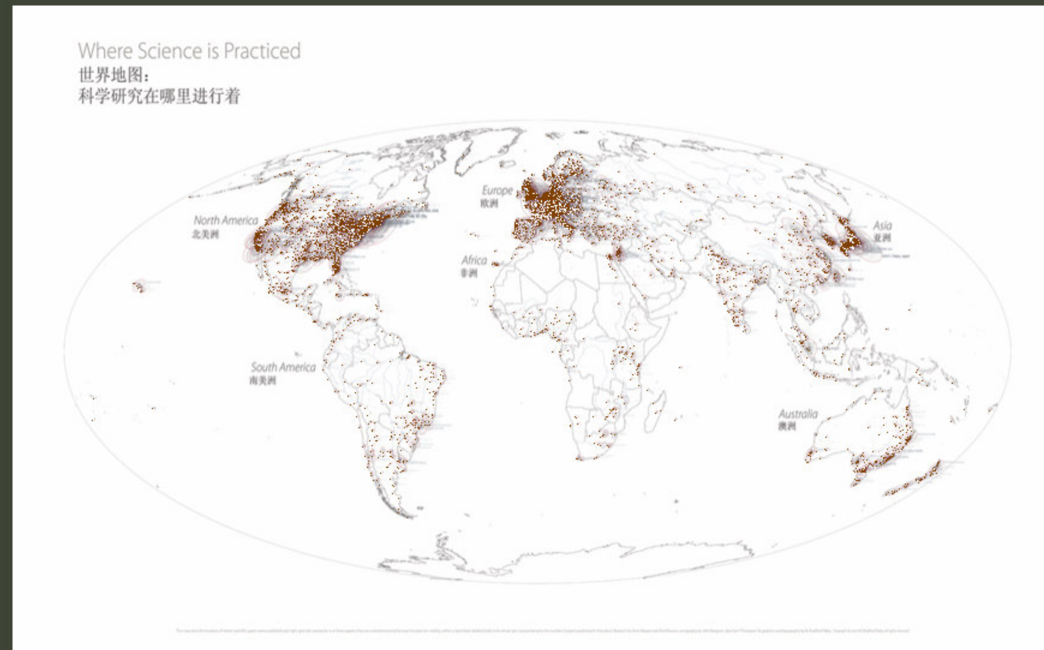
交互式科学地图展示平台





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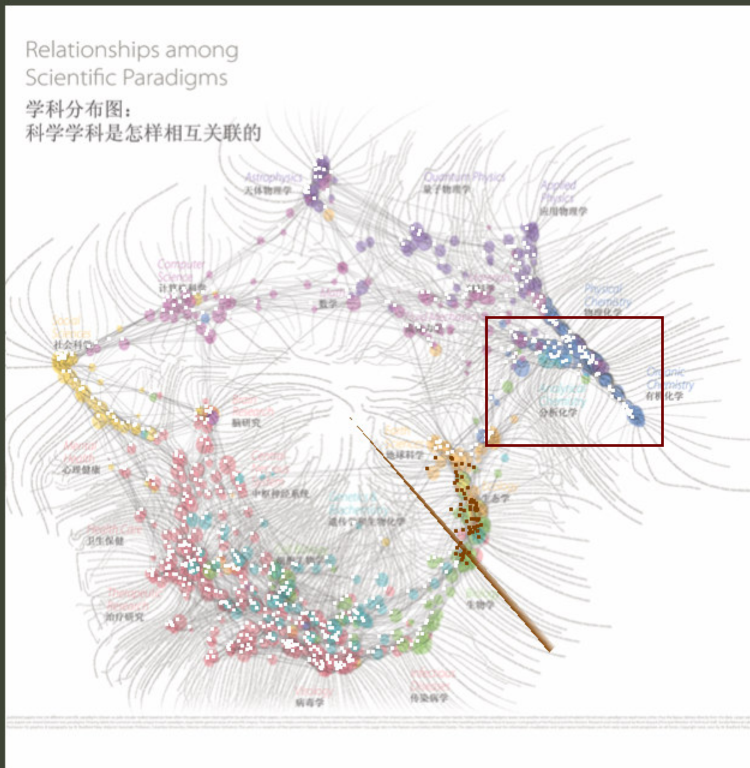

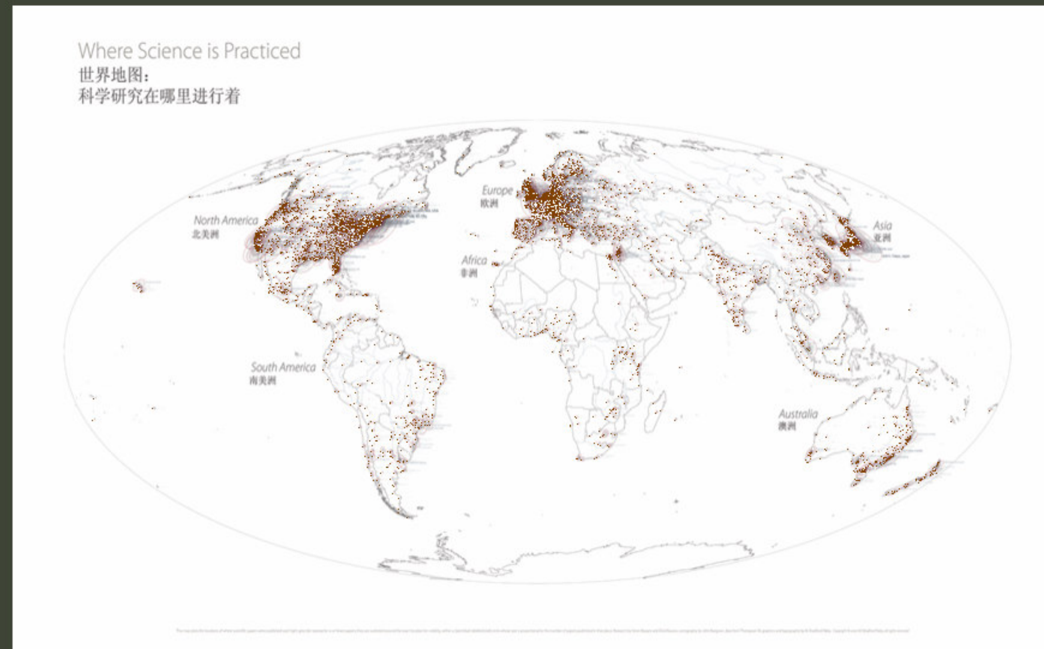

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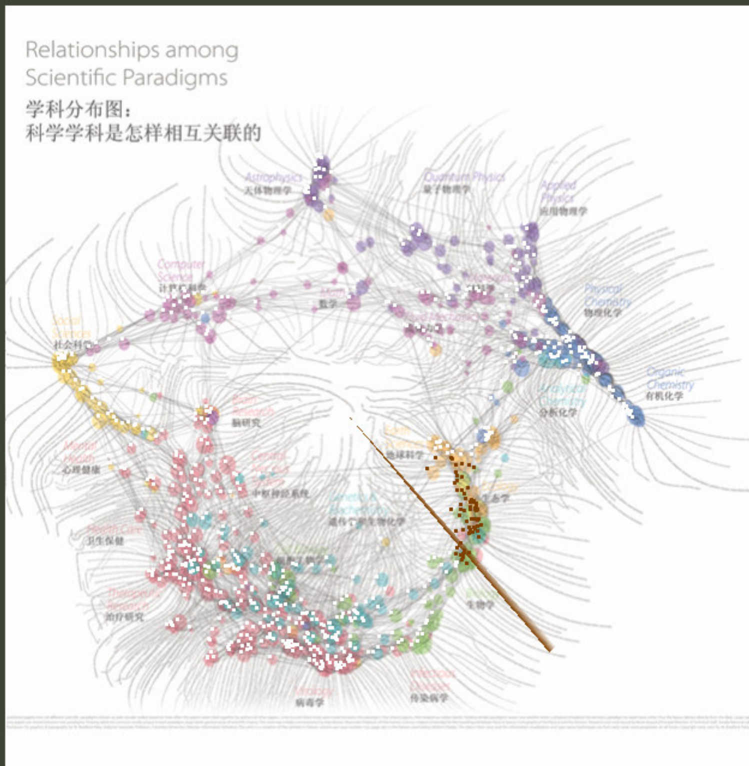

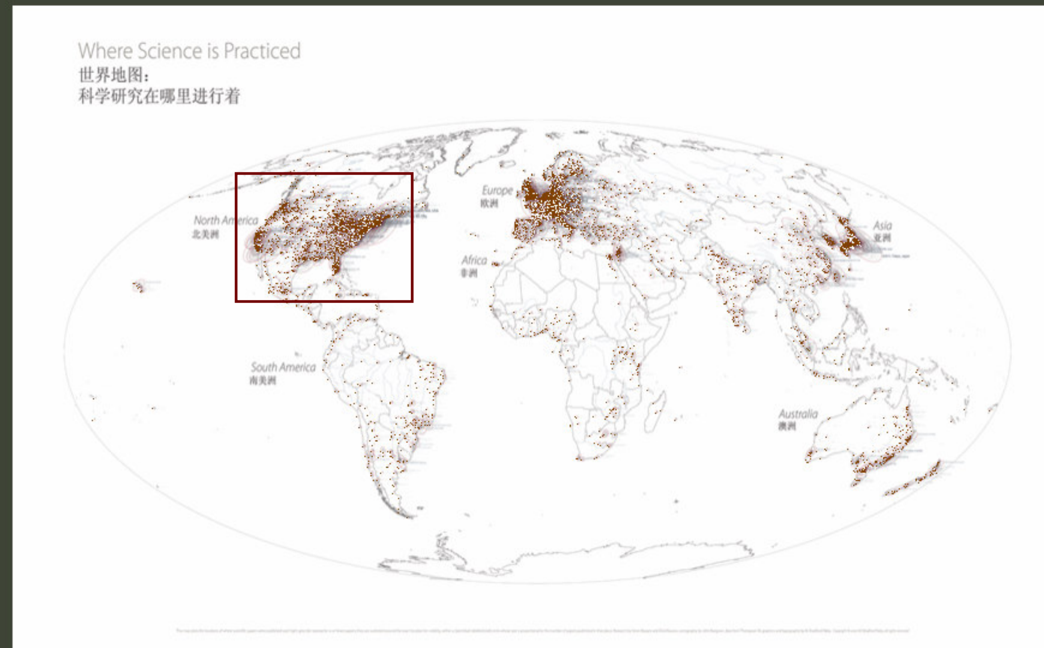

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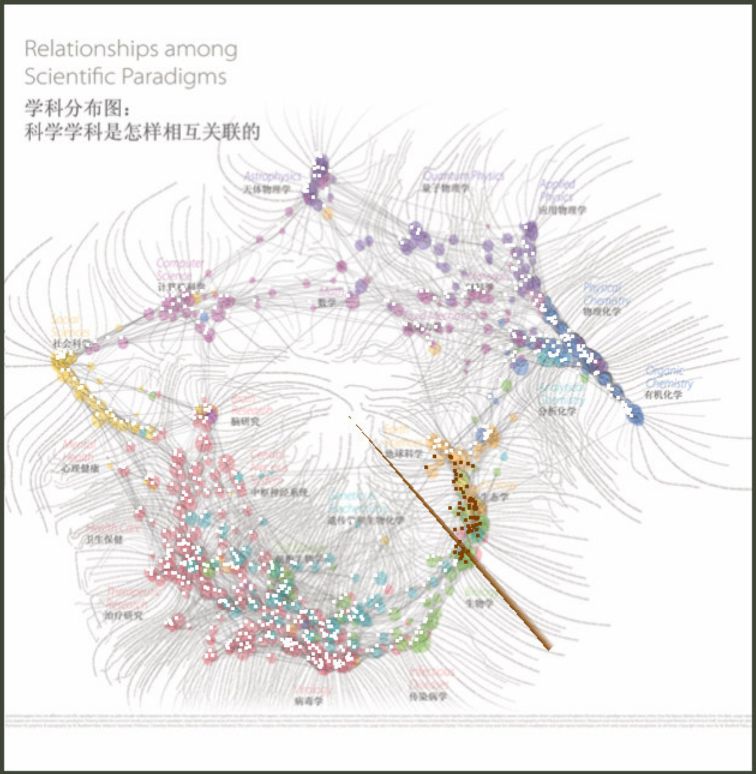
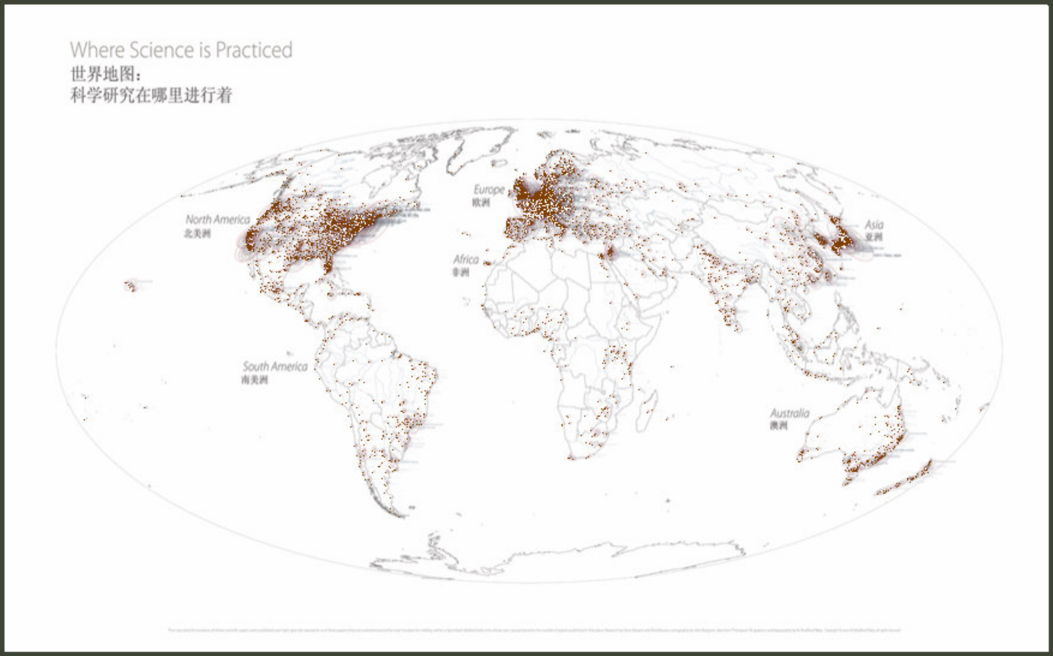
探索某个学者的科学著作的影响力的传播

弗郎西斯•科里克 DNA双螺旋状的发现者之一	阿尔伯特•爱因斯坦 用相对论重新激活了物理学	迈克尔•费舍尔 发现了物质转变模式的关键步骤	苏珊•费斯克 研究人的认知是如何产生偏见的
约舒亚•雷德伯格 细菌遗传机制研究的先驱	德里克•德索拉•普里斯 著名的“科学计量学之父”	理查德•扎尔 采用激光化学技术研究分子动态分布	关于本次展览 与此展览相关人员和机构





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位置与空间: 绘制科学地图展览的信息

- 本展览计划举办10年 (2005-2014), 每年会有10张新地图问世。到2014年，将共有100张地图完成制作。
- 2005年4月本展览的第一期最初在美国国家地理协会的年会上展出。
- 2008年5月本展览首次在中国北京以中文形式展出，并首次推出第四期 的10张新图。

第一站：中国科学院国家科学图书馆北京分馆,
2008.5.17 — 6.30

第二站：中国科学院国家科学图书馆兰州分馆,
2008.7.15 — 8.15

第三站：中国科学院国家科学图书馆成都分馆,
2008.9.1 — 10.1

第四站：中国科学院国家科学图书馆武汉分馆,
2008.10.15 — 11.15

“It is our deep belief that maps of science should show all scholarly works – published in different disciplines and countries, languages and media. They should be available to everybody in support of knowledge access, management, and utilization.

Translating many of the maps and their descriptions into Chinese and adding maps of Chinese research activity are major milestones towards this goal.

We thank the National Science Library of the Chinese Academy of Sciences for all their support in bringing the exhibit to China and we are looking forward to future collaborations.”

The Curators of the Exhibit

Dr. Katy Börner

Elisha F. Hardy

Cyberinfrastructure for Network Science Center

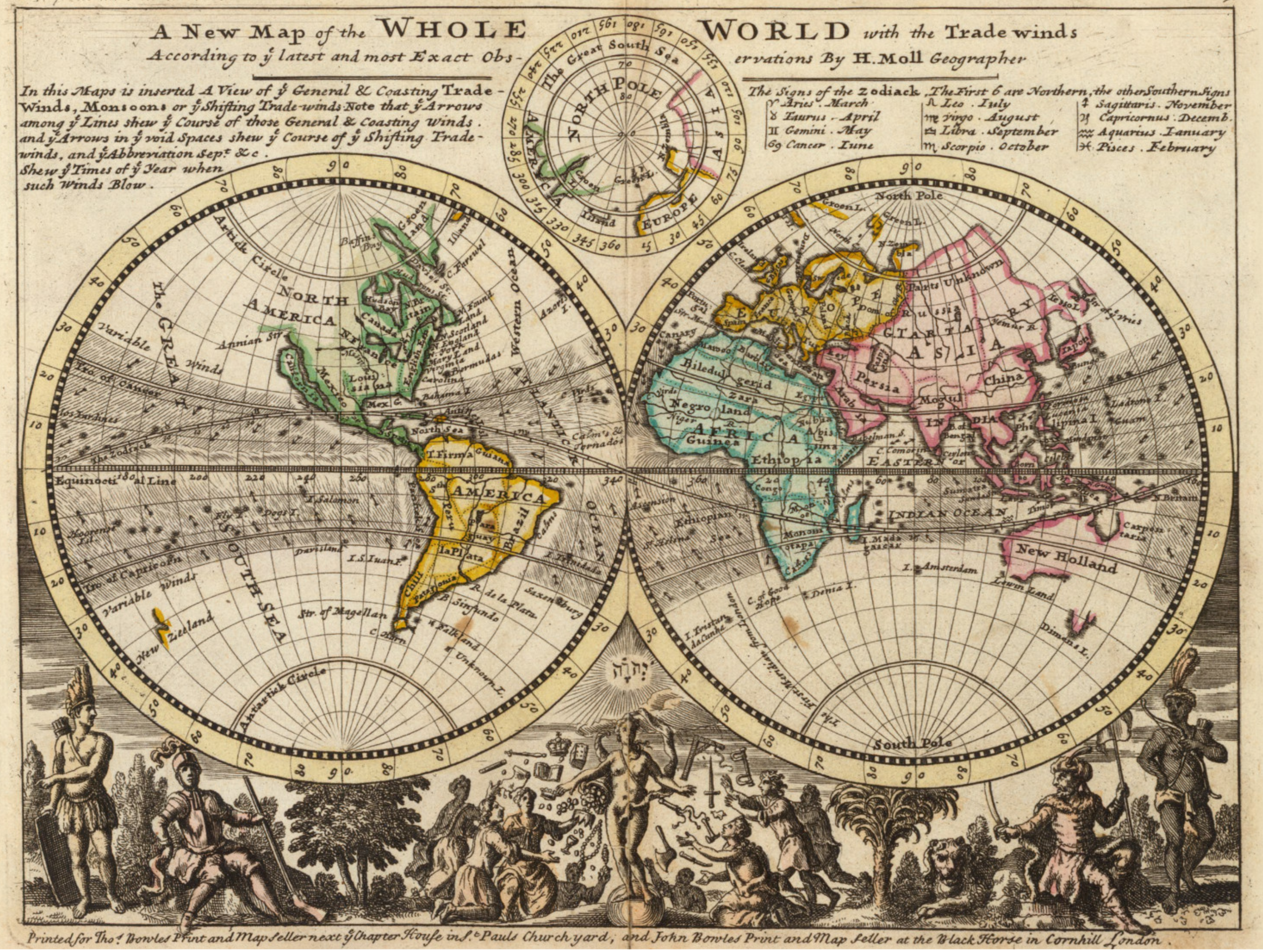
School of Library and Information Science, Indiana University, Bloomington, USA

展览的主题

- 第一期：地图的魅力（2005年）
- 第二期：参照系统（2006年）
- 第三期：预报系统（2007年）
- 第四期：科学地图对经济决策的作用（2008年）
- *第五期：为科学决策者服务的科学地图（2009年）*
- *第六期：为大中小学生为教育服务的科学地图（2010年）*
- *第七期：为科研人员、科学家服务的科学地图（2011年）*
- *。。。。。*

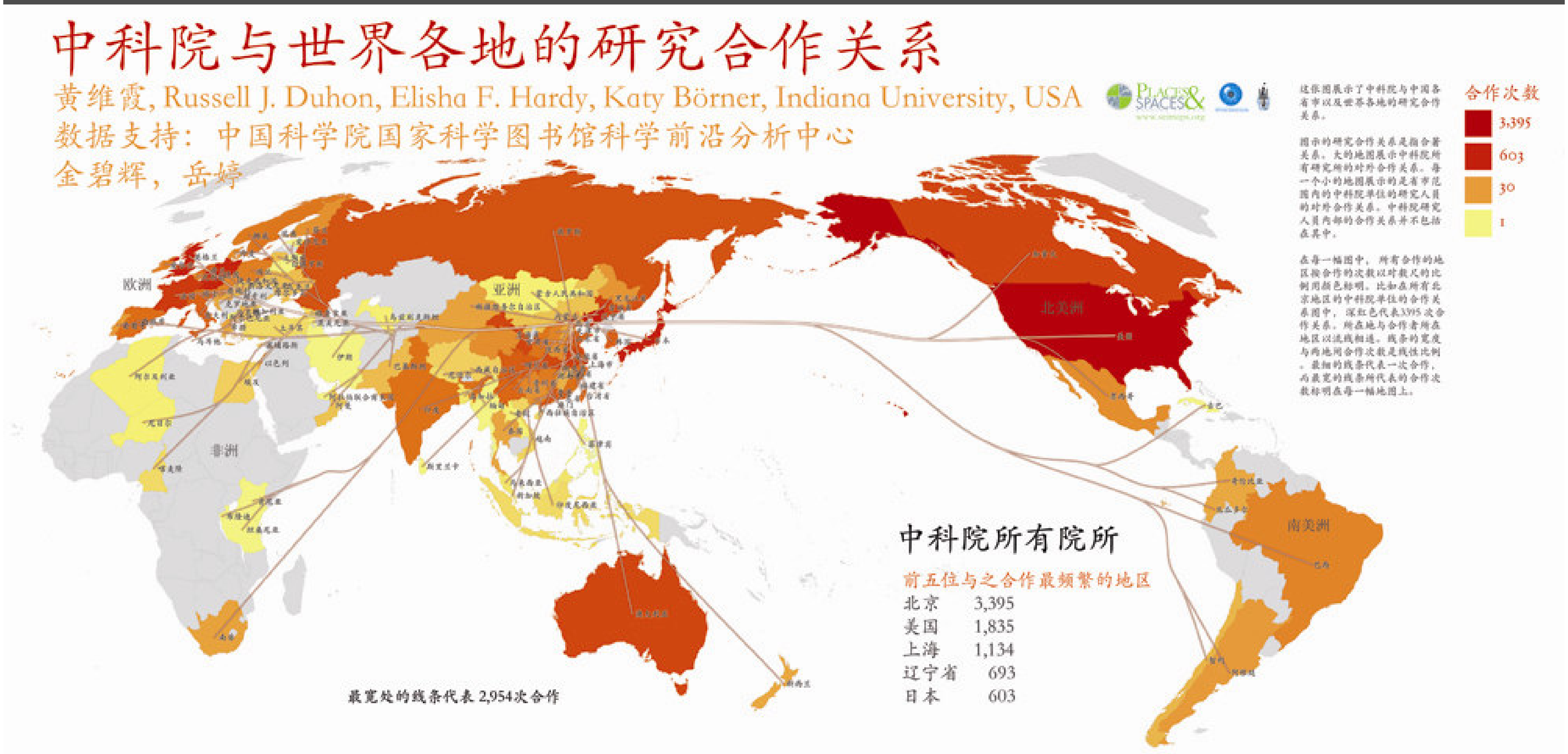
地图的历史回顾

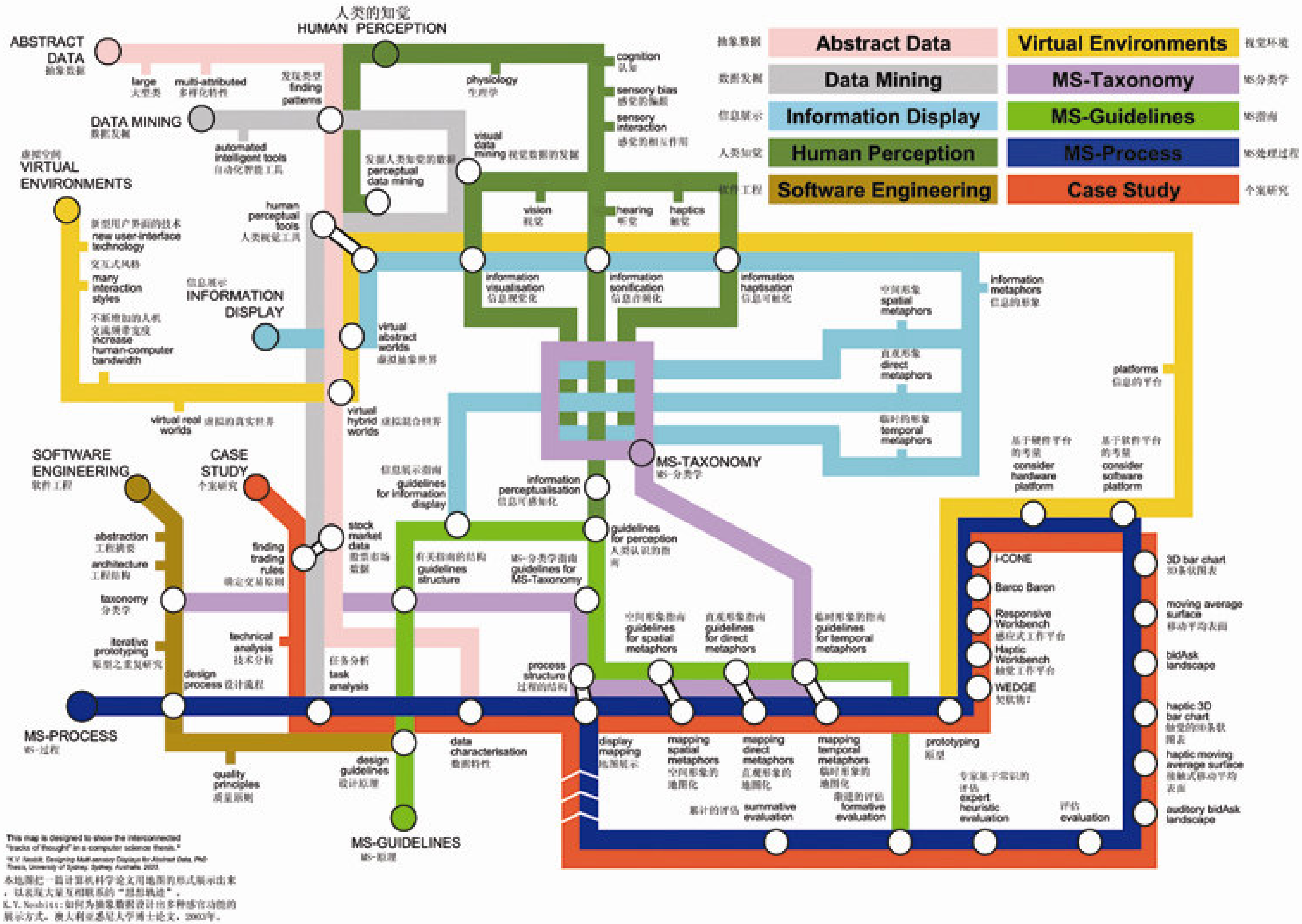

Insculptum est per Johanne Schnitzer de Armszheim
CAVRVS·CHORVS·VEL·IAPIX·SIVE·ARGESTES
CIRCIVS VEL·TRESIIAS
SEPTENTRIO·VEL·APARCTIAS
AQVILO·VEL·BOREAS
CECIAS·APELIOTES
FAVONIVS·ZEPHIRVS
SVBSOLANVS
mare glaciale
EVROPA
ASIA
LIBIA INTERIOR
AFFRICA
ARABIA FELIX
MARE·INDICVM
ETHIOPIA·INTERIOR
Circulus equinoctialis
Terra incognita secudum ptholomeum
Sinus Barbaricus
MARE
PRASODVM
Tropicus Capricorni
Gradus longitudinis ab occidente in orientem
AFRICVS·VEL·LIBS
LIBONOTVS·EVROAV·STER
AVSTER·VEL·NOTVS
EVRNOTVS
VVLTVRNVS·EVRVS


A New Map of the WHOLE WORLD with the Trade winds
According to ye latest and most Exact Observations By H.Moll Geographer
In this Maps is inserted A View of ye General & Coasting Trade-Winds, Monsoons or ye Shifting Trade-winds Note that ye Arrows among ye Lines shew ye Course of those General & Coasting Winds. and ye Arrows in ye void Spaces shew ye Course of ye Shifting Trade-winds, and ye Abbreviation Sept. &c. Shew ye Times of ye Year when such Winds Blow.
The Signs of the Zodiack, The First 6 are Northern, the other Southern Signs
♈ Aries . March
♉ Taurus . April
♊ Gemini . May
♋ Cancer . June
♌ Leo . July
♍ Virgo . August
♎ Libra . September
♏ Scorpio . October
♐ Sagittaris . November
♑ Capricornus . Decemb.
♒ Aquarius . January
♓ Pisces . February
The Great South Sea
NORTH POLE
AMERICA
ASIA
EUROPE
NORTH AMERICA
Arctick Circle
THE GREAT SOUTH SEA
Western Ocean
ATLANTICK OCEAN
Variable Winds
Tro. of Cancer
The Zodiack
Equinoctial Line
Tro. of Capricorn
AMERICA
Brazil
Peru
laPlata
Str. of Magellan
New Zeeland
Antarctick Circle
North Pole
EUROPE
Parts Unknown
GT TARTARY
ASIA
Persia
China
INDIA
AFRICA
Ethiopia
Ethiopian Sea
INDIAN OCEAN
New Holland
South Pole
Printed for Thos. Bowles Print and Map seller next ye Chapter House in St. Pauls Church yard, and John Bowles Print and Map seller at the Black Horse in Cornhill London.

科学地图是什么样？

在绘制科学地图时，什么样的表现方式是最有效的？


中科院与世界各地的研究合作关系
黄维霞, Russell J. Duhon, Elisha F. Hardy, Katy Börner, Indiana University, USA
数据支持：中国科学院国家科学图书馆科学前沿分析中心
金碧辉，岳婷
这张图展示了中科院与中国各省市以及世界各地的研究合作关系。
图示的研究合作关系是指合著关系。大的地图展示中科院所有研究所的对外合作关系。每一个小的地图展示的是省市范围内的中科院单位的研究人员的对外合作关系。中科院研究人员内部的合作关系并不包括在其中。
在每一幅图中，所有合作的地区按合作的次数以对数尺的比例用颜色标明。比如在所有北京地区的中科院单位的合作关系图中，深红色代表3395次合作关系。所在地与合作者所在地区以流线相连。线条的宽度与两地间合作次数是线性比例。最细的线条代表一次合作，而最宽的线条所代表的合作次数标明在每一幅地图上。
合作次数
3,395
603
30
1
欧洲
亚洲
非洲
北美洲
南美洲
中科院所有院所
前五位与之合作最频繁的地区
北京 3,395
美国 1,835
上海 1,134
辽宁省 693
日本 603
最宽处的线条代表 2,954次合作



HUMAN PERCEPTION
ABSTRACT DATA
Abstract Data
Data Mining
Information Display
Human Perception
Software Engineering
Virtual Environments
MS-Taxonomy
MS-Guidelines
MS-Process
Case Study
large
multi-attributed
finding patterns
cognition
physiology
sensory bias
sensory interaction
DATA MINING
automated intelligent tools
perceptual data mining
visual data mining
VIRTUAL ENVIRONMENTS
human perceptual tools
vision
hearing
haptics
new user-interface technology
many interaction styles
increase human-computer bandwidth
INFORMATION DISPLAY
information visualisation
information sonification
information haptisation
information metaphors
spatial metaphors
direct metaphors
temporal metaphors
virtual abstract worlds
virtual real worlds
virtual hybrid worlds
platforms
SOFTWARE ENGINEERING
CASE STUDY
MS-TAXONOMY
guidelines for information display
information perceptualisation
guidelines for perception
consider hardware platform
consider software platform
abstraction
architecture
taxonomy
iterative prototyping
finding trading rules
stock market data
guidelines structure
guidelines for MS-Taxonomy
technical analysis
task analysis
design process
process structure
guidelines for spatial metaphors
guidelines for direct metaphors
guidelines for temporal metaphors
i-CONE
Barco Baron
Responsive Workbench
Haptic Workbench
WEDGE
3D bar chart
moving average surface
bidAsk landscape
haptic 3D bar chart
haptic moving average surface
auditory bidAsk landscape
MS-PROCESS
quality principles
design guidelines
data characterisation
display mapping
mapping spatial metaphors
mapping direct metaphors
mapping temporal metaphors
prototyping
summative evaluation
formative evaluation
expert heuristic evaluation
evaluation
MS-GUIDELINES


forest
soil
climat
chang
urban
model
spatial
temperatur
transport
plan
city
popul
precipit
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weather
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immigr
health
remot
channel
flow
river
water
land
site analysi
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labor
commun
flood
town
home
women
manag
maps
state
natur
develop
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work
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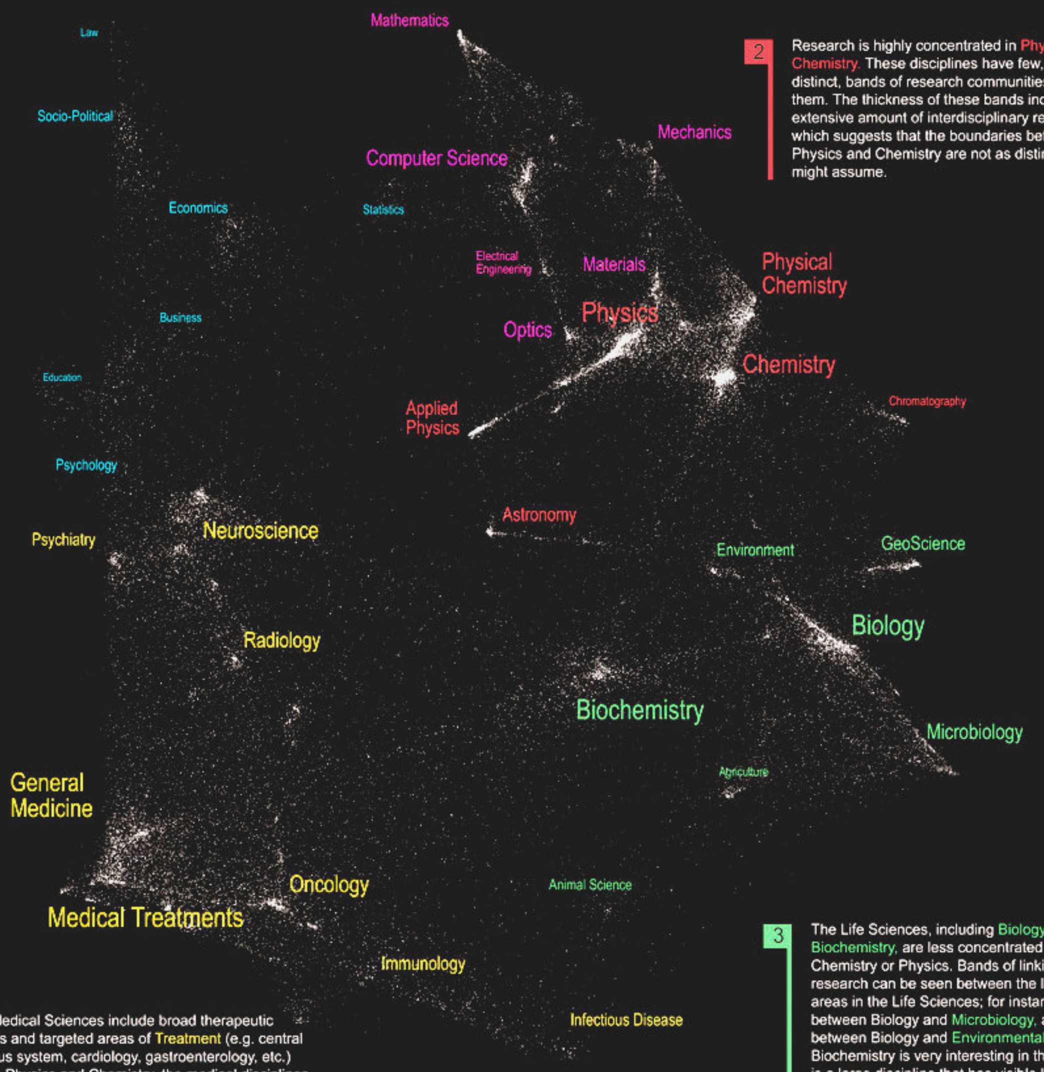
The Structure of Science

5 The Social Sciences are the smallest and most diffuse of all the sciences. Psychology serves as the link between Medical Sciences (Psychiatry) and the Social Sciences. Statistics serves as the link with Computer Science and Mathematics.

1 Mathematics is our starting point, the purest of all sciences. It lies at the outer edge of the map. Computer Science, Electrical Engineering, and Optics are applied sciences that draw upon knowledge in Mathematics and Physics. These three disciplines provide a good example of a linear progression from one pure science (Mathematics) to another (Physics) through multiple disciplines. Although applied, these disciplines are highly concentrated with distinct bands of research communities that link them. Bands indicate interdisciplinary research.

2 Research is highly concentrated in Physics and Chemistry. These disciplines have few, but very distinct, bands of research communities that link them. The thickness of these bands indicates an extensive amount of interdisciplinary research, which suggests that the boundaries between Physics and Chemistry are not as distinct as one might assume.



3 The Life Sciences, including Biology and Biochemistry, are less concentrated than Chemistry or Physics. Bands of linking research can be seen between the larger areas in the Life Sciences; for instance between Biology and Microbiology, and between Biology and Environmental Science. Biochemistry is very interesting in that it is a large discipline that has visible links to disciplines in many areas of the map, including Biology, Chemistry, Neuroscience, and General Medicine. It is perhaps the most interdisciplinary of the sciences.

4 The Medical Sciences include broad therapeutic studies and targeted areas of Treatment (e.g. central nervous system, cardiology, gastroenterology, etc.) Unlike Physics and Chemistry, the medical disciplines are more spread out, suggesting a more multi-disciplinary approach to research. The transition into Life Sciences (via Animal Science and Biochemistry) is gradual.

We are all familiar with traditional maps that show the relationships between countries, provinces, states, and cities. Similar relationships exist between the various disciplines and research topics in science. This allows us to map the structure of science.

One of the first maps of science was developed at the Institute for Scientific Information over 30 years ago. It identified 41 areas of science from the citation patterns in 17,000 scientific papers. That early map was intriguing, but it didn't cover enough of science to accurately define its structure.

Things are different today. We have enormous computing power and advanced visualization software that make mapping of the structure of science possible. This galaxy-like map of science (left) was generated at Sandia National Laboratories using an advanced graph layout routine (VxOrd from the citation patterns in 800,000 scientific papers published in 2002. Each dot in the galaxy represents one of the 96,000 research communities active in science in 2002. A research community is a group of papers (9 on average) that are written on the same research topic in a given year. Over time, communities can be born, continue, split, merge, or die.

The map of science can be used as a tool for science strategy. This is the terrain in which organizations and institutions locate their scientific capabilities. Additional information about the scientific and economic impact of each research community allows policy makers to decide which areas to explore, exploit, abandon, or ignore.

We also envision the map as an educational tool. For children, the theoretical relationship between areas of science can be replaced with a concrete map showing how math, physics, chemistry, biology and social studies interact. For advanced students, areas of interest can be located and neighboring areas can be explored.

Nanotechnology

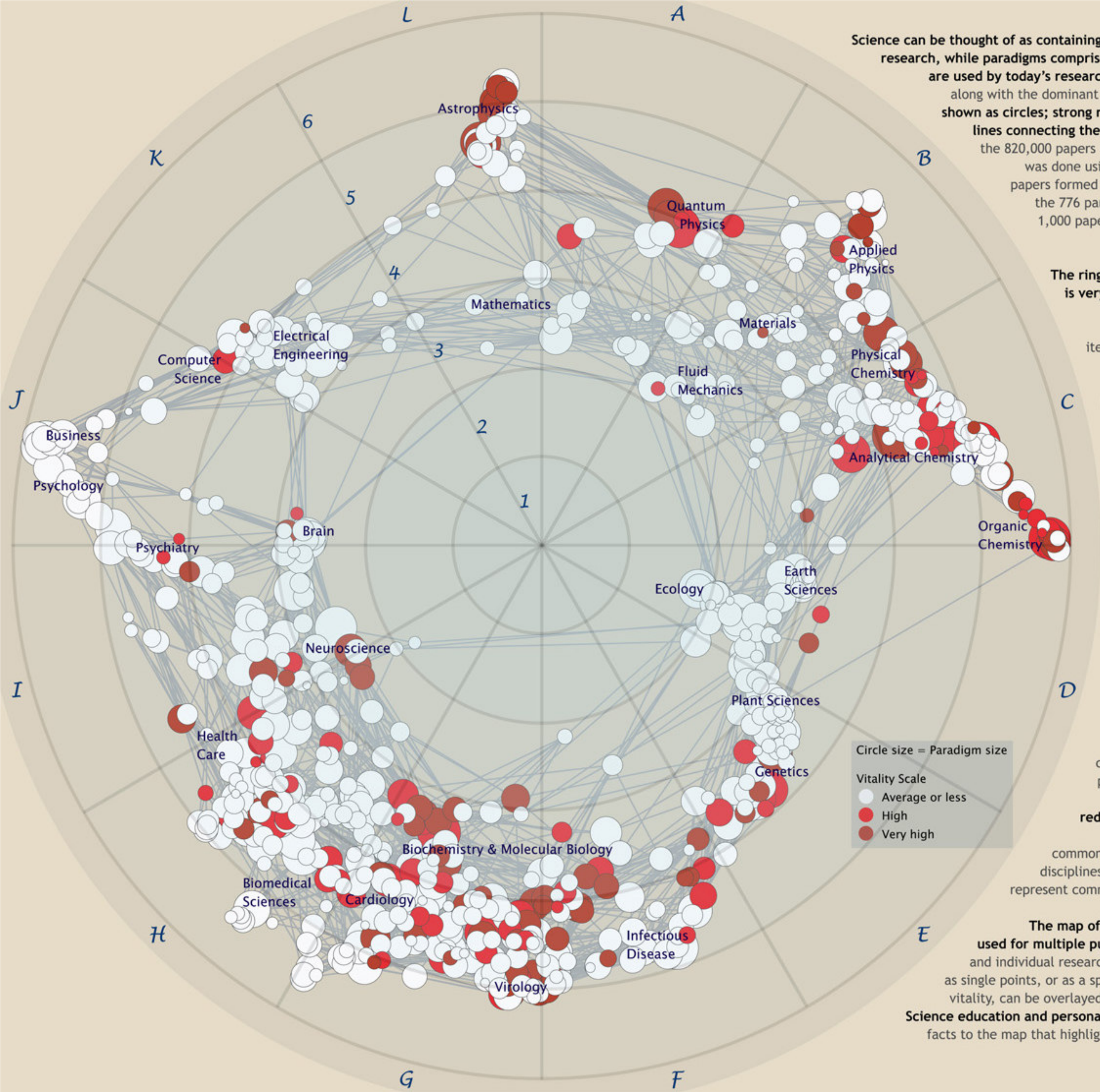
Most research communities in nanotechnology are concentrated in Physics, Chemistry, and Materials Science. However, many disciplines in the Life and Medical Sciences also have nanotechnology applications.

Proteomics

Research communities in proteomics are centered in Biochemistry. In addition, there is a heavy focus in the tools section of chemistry, such as Chromatography. The balance of the proteomics communities are widely dispersed among the Life and Medical Sciences.

Pharmacogenomics

Pharmacogenomics is a relatively new field with most of its activity in Medicine. It also has many communities in Biochemistry and two communities in the Social Sciences.



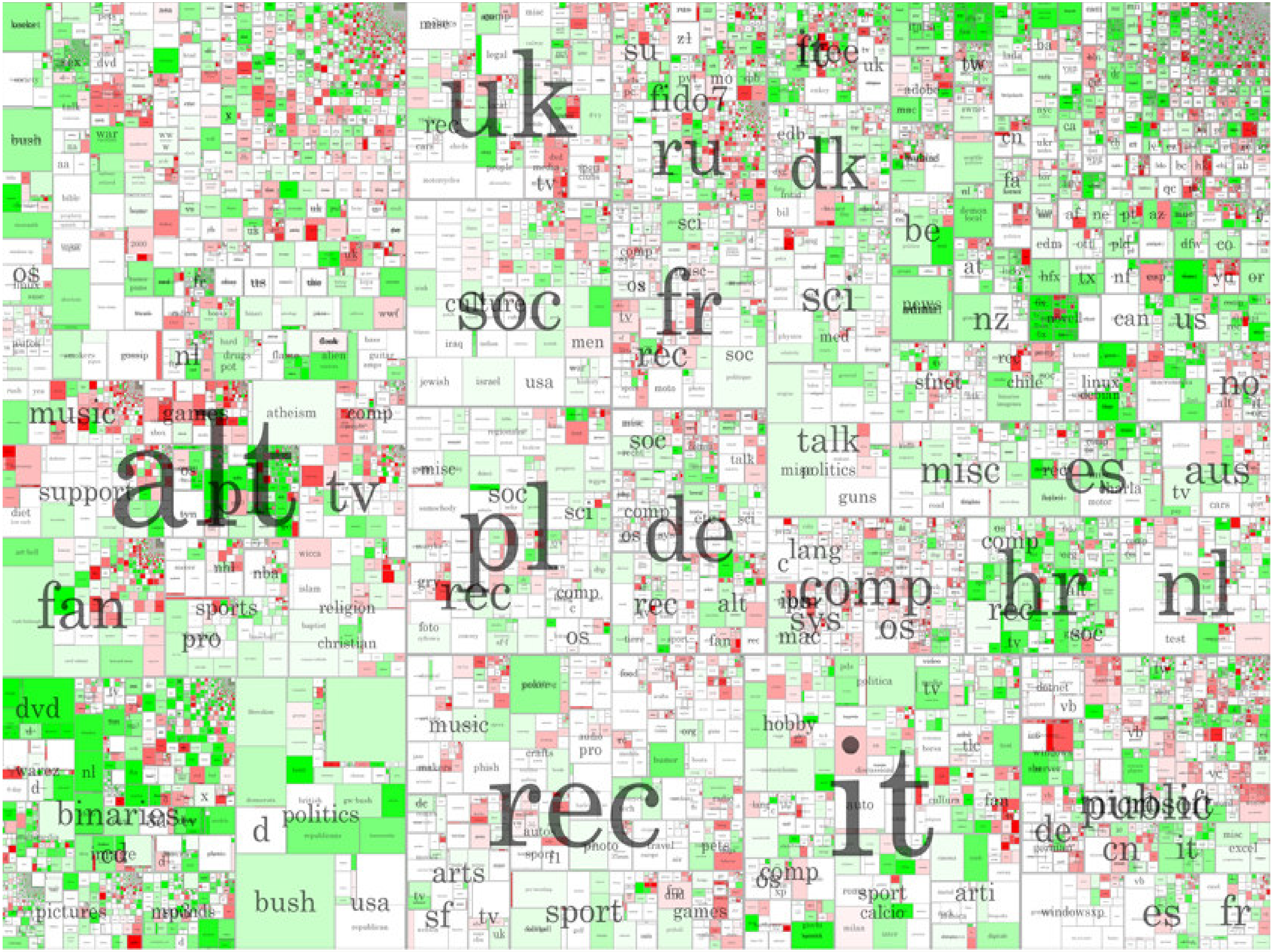
Science can be thought of as containing themes and paradigms. Themes are areas of current research, while paradigms comprise the dominant tool sets and existing knowledge that are used by today's researchers. This map shows **776 major paradigms in science** along with the dominant relationships between these paradigms. **Paradigms are shown as circles; strong relationships between paradigms are indicated by the lines connecting the circles.** The map was created by recursively clustering the 820,000 papers referenced most often in 2003. Clustering at each level was done using VxOrd, a force-directed graph layout routine. These papers formed 53,000 clusters, 6,100 higher-level clusters, and finally the 776 paradigms. Although each paradigm contains, on average, 1,000 papers, some are larger and some are smaller, as shown by different sized circles on the map.

The ring-like structure that is formed by scientific paradigms is very robust. We find similar structures for different years, and for maps generated from scientific journals. "The Structure of Science", a galaxy map shown in the first iteration of Places & Spaces, is a map based on clustering of scientific journals, with superimposition of papers on the journal structure, whereas this map was generated directly from highly-cited papers. "The Structure of Science" shows current science in a disciplinary context, while this map can show the breadth of disciplines that contribute to single paradigms.

Because of the robust nature of the structure of science and its paradigms, we have placed our 776 scientific paradigms within a **reference system containing 12 radial slices and 6 rings.** This allows the position of each paradigm to be codified and available for lookup; for instance ***Fluid Mechanics*** **paradigms are in grid B3.**

We have also calculated and displayed the vitality of each paradigm. ***Vitality*** **is a measure of the speed at which a group of researchers reaches consensus about major improvements.** Paradigms are constantly being improved, but it usually takes years to reach consensus about which improvements are major. The white circles represent communities where consensus is reached relatively slowly. This is a common phenomenon in the social sciences, ecological sciences, computer sciences, and mathematics disciplines. **The red circles represent communities of researchers where consensus is reached relatively rapidly.** This is more common in physics, chemistry, biochemistry, and many medical disciplines. Very dark circles (such as those in *Astrophysics, L5-6*) represent communities where consensus is reached extremely quickly.

The map of scientific paradigms and its reference system can be used for multiple purposes. Countries, industries, companies, universities, and individual researchers can all **locate themselves within the map**, either as single points, or as a specific collection of paradigms. Various metrics, such as vitality, can be overlayed on this reference system to highlight specific impacts. **Science education and personal discovery** can also be enhanced by linking stories and facts to the map that highlight scientific history, current advances and relationships between scientific paradigms.



alt
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fan
sports
religion
christian
atheism
wicca
islam
dvd
binaries
pictures
politics
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uk
soc
men
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israel
usa
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sci
comp
os
foto
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music
phish
arts
sf
tv
sport
ru
su
fido7
fr
soc
de
alt
fan
sci
talk
guns
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comp
os
mac
it
hobby
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test
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fr
excel

科学地图可以用来分析展示各种数据

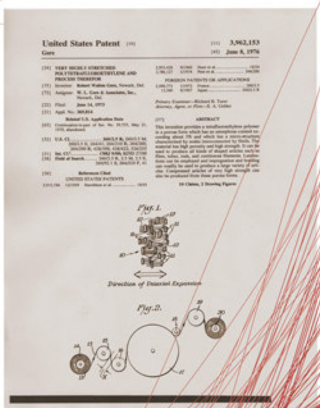
US Patent Hierarchy

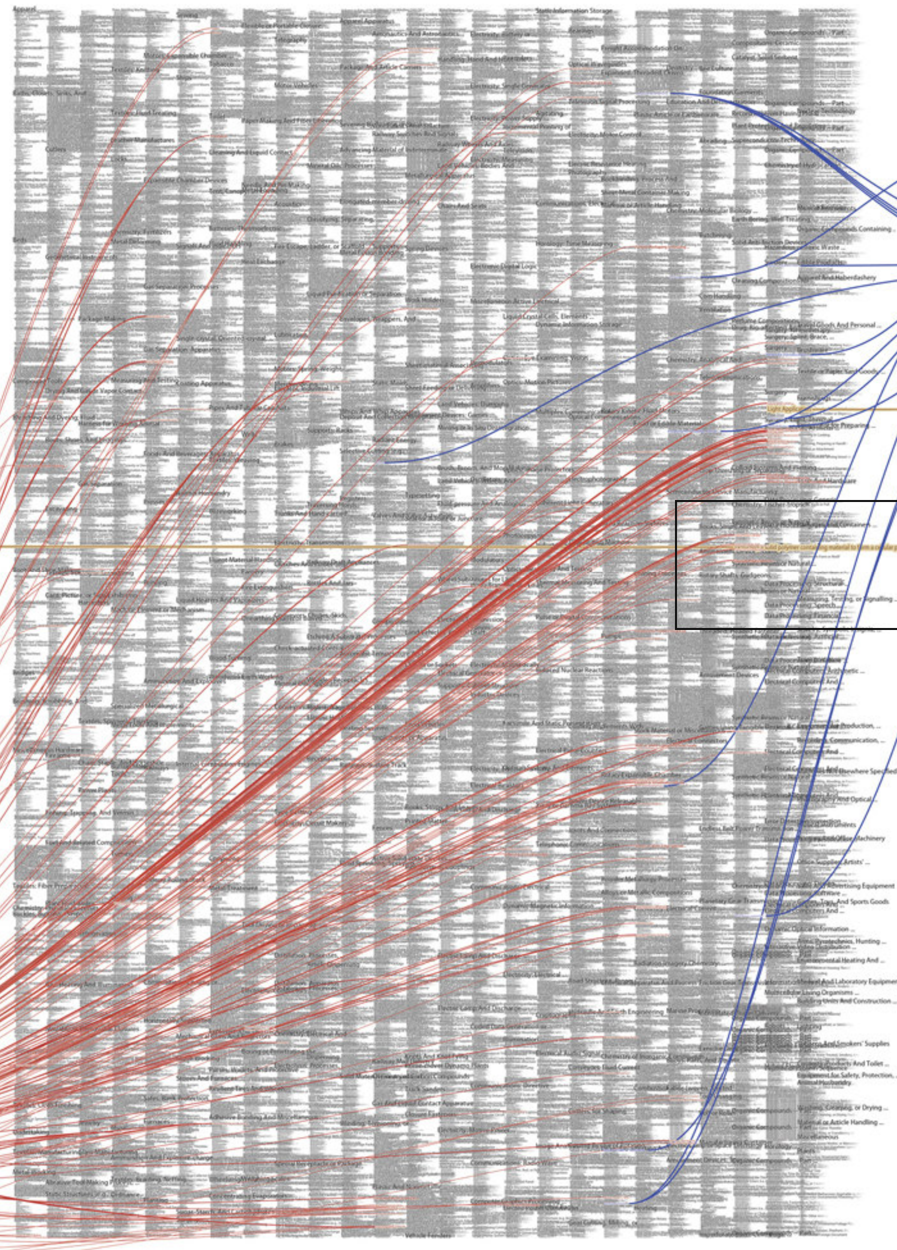
Impact

The United States Patent and Trademark Office does scientists and industry a great service by granting patents to protect inventions. Inventions are categorized in a taxonomy that groups patents by industry or use, proximate function, effect or product, and structure. At the time of this writing there are 160,523 categories in a hierarchy that can get as deep as 15 levels. We display the first three levels (13,529 categories) at right in what might be considered a textual map of inventions.

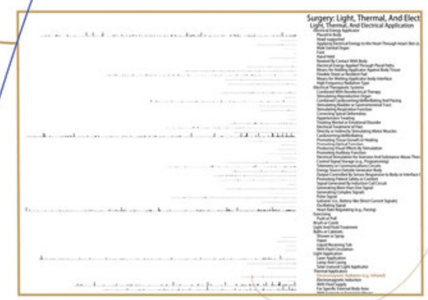
Patent applications are required to be unique and non-obvious, partially by revealing any previous patents that might be similar in nature or provide a foundation for the current invention. In this way we can trace the impact of a single patent, seeing how many patents and categories it affects.

The patent on Goretex—a lightweight, durable synthetic fiber—is an example of one that has had significant impact. The box below enlarges the section of the hierarchy where it is filed, and the red lines (arranged to start along a time line from 1981 to 2006) point to the 130 categories that contain 182 patents, from waterproof clothing to surgical cosmetic implants, that mention Goretex as prior art.





Prior Art



New patents often build on older ideas from many categories. Here, blue lines originate in sixteen different categories that contain the patents cited as prior art for a patent on "gold nanoshells." Gold nanoshells are a new invention: tiny spheres (with a diameter ten million times smaller than a human hair) that can be used to make tumors more visible in infrared scans, and have even helped cause complete remission of tumors in tests with laboratory mice. The blue lines show that widely separated categories provided background for this invention.

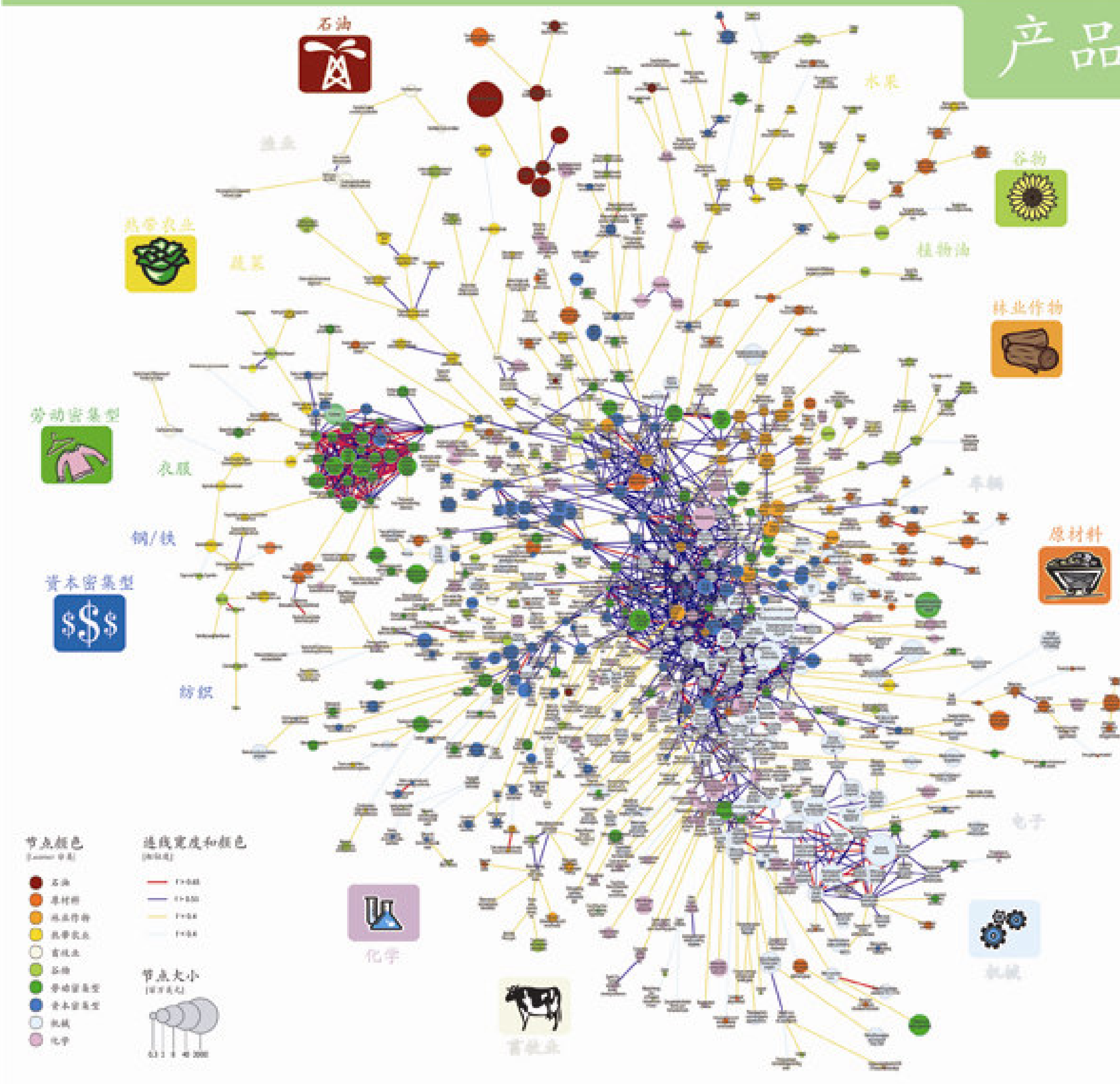
Keeping categories understandable is an important part of maintaining any taxonomy, including the patent hierarchy. Categories are easier to understand, search, and maintain if they contain elements (patents in this case) that fit well within the definition of the category. The box above shows a tiny bar chart, part of a "Taxonomy Validator" that helps people decide whether categories are good ones.

Categories can be redefined or combined, and sometimes need to be split when they becomes too large; a constant problem shared by many classifications systems in this information-rich century. But how can we determine exactly where to split a category in two, for example--if there are hundreds or thousands of elements in it?

The Taxonomy Validator measures a "distance to prototype:" how far each element is from an idealized "prototype" element for each bucket. This can be based on statistics, computational comparisons of words, or even human judgement. A simple bar chart can then show how good a category is. A good category has lots of small bars; a generally ragged category is one that might need scrutiny or reorganization; while one that has only one or two tall bars may just mean that one or two elements don't belong. Even simple visualizations like this can ease knowledge work by showing the eye much more than can fit into memory as words; focusing people on just the right issues, and providing a vastly broader background to support more informed judgements.


Extruding a solid polymer containing material to
Coating Processes
Rotary Shafts, Gudgeons, ...
Synthetic Resins or Natural ...
Data Processing: Structural ...
Measuring, Testing
Data Processing: Speech ...
Data Processing: Financial, ...
Threaded, Headed Fastener, ...
Jewelry, Symbolic
Transportation
Electrical Computers: Arithmet
Amusement Devices
Electrical Computers And ...
Foraminous Product Produced
Insulative Material Deposited ...
Organic Coating Applied ...
Simulative In Form or Motif
Calibration or Correction System
Nonuniform Coating
Including Coating or Material Removal
Measuring, Regulating or Indicating
Flag or Pennant
Vehicle Drawn By Animal
Computer Conferencing

产品空间结构图

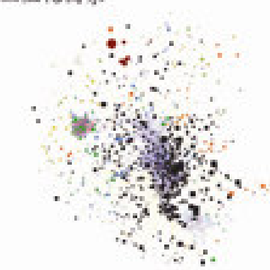


世界贸易流量数据由Feenstra等人采集，可以从美国国家经济研究署得到。依据这些数据生成了从1998年到2000年775种工业产品的共同出口全矩阵。利用最大支撑树算法删去矩阵中相互连接小于1%的产品，同时综合考虑每种产品的共同出口频次，选择阈值大于0.55的产品，然后采用力支撑布局算法形成最终的产品空间网络。节点的大小代表产品贸易值（单位为百万美元），根据Leamer提出的产品分类思想，节点的颜色对应着10个产品组。每组产品的等级由一种图标表示。连线的颜色与宽度代表相关产品共同出口的频次。

经济覆盖区

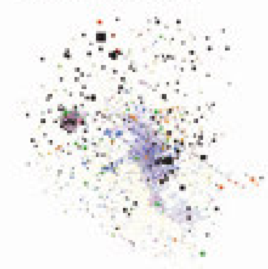
■ 指示相关出口

工业化国家



东亚太平洋地区

拉美和加勒比海地区



产品空间网络展示了一种核心-边缘结构：具有较高价值的产品等级，如机械设备和化学制品处于网络的核心位置；而那些品质等级较低的渔业和服装产品则位于网络的边缘。同时，处于网络核心的产品，其内部关联密切，而那些处于网络边缘的产品则内部关系松散。

每个国家都有一个产品出口量的报表。工业发达国家、东亚太地区、拉美及加勒比海地区的出口数据列在右边的表中。

传统的增长理论认为在一定的范围内总会有一种更先进的产品。然而，这里产品空间的核心-边缘结构却说明产品之间的距离有远有近，变化不一。

处于核心位置的国家拥有研发和制造多种多样产品的能力，而处于边缘地带的大部分国家却很少有产品多样化的发展机会。一个国家现有的产品生产制造的能力以及产品空间的结构对该国未来的发展会产生重大影响。

总　　结

- 科学地图有广阔的应用前景
- 科学地图研究与开发还存在很多的挑战
- 通过这次活动, 这个展览, 有更多的人继续关注科学地图的发展

http://scimaps.org

huangb@indiana.edu

鸣　　谢

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