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Is there a Convergent Structure of Science? A Comparison of Maps using the ISI and Scopus Databases[1]

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Abstract
This article compares two maps of science that are built from different, but highly representative sets of the world-wide scientific literature. The analysis in this article extends existing work in this area in three major ways. First, we provide quantitative comparisons of the ISI and Scopus databases for 15 areas of science. Second, we illustrate how these differences have an impact on the resultant map of science. Third, we argue that these differences do not affect the fundamental shape and structure of science; the differences create local differentiation and improve our understanding of local relationships. We conclude with a discussion about the value of generating a convergent map of science.

Keywords
Map of science; journal coverage; ISI-Scopus comparison; co-citation analysis

Introduction

Maps of science are visual representations of the relationships between different areas of science. These maps allow us to better understand the relationships between mathematics, physics, chemistry, biochemistry, biology, earth sciences, medical sciences, social sciences, computer sciences and engineering. Accurate maps of science can significantly contribute to our understanding of how science is structured and how it evolves. Maps of science, if they accurately reflect the underlying structure of scientific behavior, can play a central role in education and the communication of scientific issues to the general public.

The intent of this paper is to explore the possibility that there is a convergent structure to science. More specifically, will different databases or methodologies generate pictures representing the structure of science that are structurally equivalent? Convergence, if it exists, can have a significant effect on education. Maps of science can have the same role in education as maps of the world. For example, can you imagine learning about world history without a map of the world? Yet this is what we do today in the sciences; we teach about each area of science as if it exists as an isolated country.

We will start the exploration of convergence by comparing maps based on two databases. These databases have slightly different coverage. The ISI database, which has been the standard in this field for the past 30 years, covers the scientific literature, the social sciences and the humanities. The Scopus database, which is significantly larger in size and scope, covers more of the international literature, more of the engineering literature and excludes the humanities.

The paper is organized into four sections. In the first section, we present our methodology for generating a map or model of science from a database of scientific papers. Using the ISI and Scopus databases we generate two separate maps of science, and then compare them in a qualitative way. We then compare the two maps more quantitatively by analyzing journal and paper coverage for fifteen

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areas of science. The final section discusses the value of a convergent map of science and the need for additional research on this topic.

Mapping Methodology

Maps of science have been published for several decades. Early maps (Griffith, Small, Stonehill, & Dey, 1974) were necessarily small, used severe thresholds, and only represented a small fraction of the available papers. As time has passed, the resources for generating maps have increased such that maps of millions of papers are now possible. For this study, we followed the same basic procedures that we have previously used to generate large maps of science. Although the procedure has been previously described in the literature (Klavans & Boyack, 2006b), we give a brief discussion of each step here.

1) Given that our goal is a convergent map of "all of science", the first step is to identify databases of scientific articles that represent activity in a broad set of scientific disciplines and include extensive citation data. Historically, the ISI databases provided by Thomson Scientific had been the only databases that met this initial criterion. ISI databases cover a broad set of scientific disciplines and have been the standard in the field for conducting international comparisons of scientific publication. Elsevier, the largest publisher of scientific journals, introduced a competitive database in 2005. Their Scopus database covers many of the major scientific journals that ISI covers. In addition, Scopus appears to have greater coverage of selected scientific areas (computer science, engineering, clinical medicine and biochemistry). It is also claimed to have greater coverage of the international literature, especially from Asia and the Far East. We have thus generated individual maps from both the ISI and Scopus citation databases.

2) Selecting an appropriate time slice of data is a necessary step in any mapping exercise. There are two main approaches: a narrow time slice, and a broad time slice. A broad time slice assumes that the structure of science is extremely stable over time. Evolution of science is then shown on this structural framework (Chen, 2006). In this study, we use a relatively narrow time slice, specifically because of the belief that the structure of science may not be stable over time. We limit each of our maps to a single year of data, the 2004 indexing year, for both the ISI and Scopus maps. One year is sufficiently long to damp out the effects of single issues of particular journals and different publication rates, but short enough to create a representative map, or snapshot, of science.

3) References, or cited papers, were used as the basic unit of analysis. There are three general approaches that are commonly used to generate the structural elements in a map of science. The first is to use the journal as the unit of analysis, and corresponding maps represent the disciplinary structure of science. A second is to use current papers as the unit of analysis; corresponding maps represent themes, or topics of research, for that year of data. A third approach is to use the reference papers as the unit of analysis. In this case the corresponding maps represent paradigms that researchers build upon.

We did not choose to generate a disciplinary map of science in this study. The methodology for generating disciplinary maps has required that each journal occupy one, and only one position (Boyack, Klavans, & Börner, 2005). We believe that this can violate the very nature of the phenomena. Many journals cover multiple disciplines (especially journals where the strategy is to report on developments in all of science). We do not believe that a disciplinary map, based on the restriction of single positions for every journal, will provide the most accurate representation of the structure of science.

In this study, we choose to generate a paradigm map (clustering the references) instead of a thematic map (clustering the current articles). Either would serve the purposes of this study. However, given our assumption that current themes or topics change more rapidly than the underlying paradigms that people use, we expected that thematic maps might be less convergent over time. We plan to explore these issues in future studies.

4) Thresholds are commonly used so that only the most important references are included in a map of science. We use an extremely low threshold[2] so that all disciplines are well represented. For a discussion of the effect of thresholds on disciplinary bias, see (Klavans & Boyack, 2006b). The threshold resulted in 1,895,118 unique references from the ISI database (out of a possible 12,509,925). The threshold resulted in 2,100,129 unique references from the Scopus database (out of a possible 13,273,040).

5) There are many alternative measures of paper-paper relatedness that have been proposed in the literature (cf. Jones & Furnas, 1987). We use a distance measure that was recently shown to be the most accurate measure available (Klavans & Boyack, 2006a).

6) The references are clustered using the distance measure and an average link clustering algorithm (Klavans & Boyack, 2006b). Each cluster represents a research community – a group of researchers using a specific approach to a problem. These clusters are sometimes referred to as specialities by other researchers.

Previous attempts to cluster extremely large sets of scientific references have used single link clustering because of computational efficiency. Average link clustering is preferable, but requires approximately n^2 calculations. We were able to improve the computation efficiency of an average link clustering algorithm to $n\log n$ time through the use of the distance measure, which is calculated using an interim dimensional reduction step (Klavans & Boyack, 2006a, 2006b).

7) We follow a hierarchical clustering procedure, first suggested by Small (Small, Sweeney, & Greenlee, 1985), to continue to cluster the clusters using the same measure of relatedness and clustering algorithm. In essence, this requires a repeating of steps 5 and 6 above. No information is thrown away at each subsequent level of clustering – the original co-citation counts are aggregated to the appropriate clusters and levels. We stopped the hierarchical clustering when there were less than 1000 nodes (this represented four levels of clustering). This higher level of aggregation represents paradigms.

8) Current papers (those indexed in 2004) are assigned to the paradigms, or clusters of references, using the references in the current papers. 864,961 current papers from 8,408 journals in the ISI database were assigned to the 1,895,118 clustered references. There were 1,081,216 current papers from 11,877 journal or conference titles assigned to the 2,100,129 clustered references in the Scopus database.

9) A visualization algorithm was used to generate a layout of paradigms (Davidson, Wylie, & Boyack, 2001; Klavans & Boyack, 2006b), thus creating visual maps for the ISI and Scopus models. We selected an edge cutting setting that generated similar pictures, in terms of white space and node spacing, from both databases. Pajek (Batagelj & Mrvar, 1998) was used to generate the final pictures of each map.

Maps of Science

Figure 1 is a comparison of the maps of science from the Scopus and ISI databases for 2004. The nodes represent paradigms, or clusters of references. The size of the node corresponds to the number of current papers that were assigned to each of the paradigms. The lines between nodes represent strong relationships between clusters of scientific references. Only the primary relationships, selected by the visualization software, are shown in these graphs.

[2] For references published in the year prior to the indexing year (in this case, 2003), any reference with 3 or more co-citations with any other reference is included. For all older references, a threshold of 4 co-citations is used.

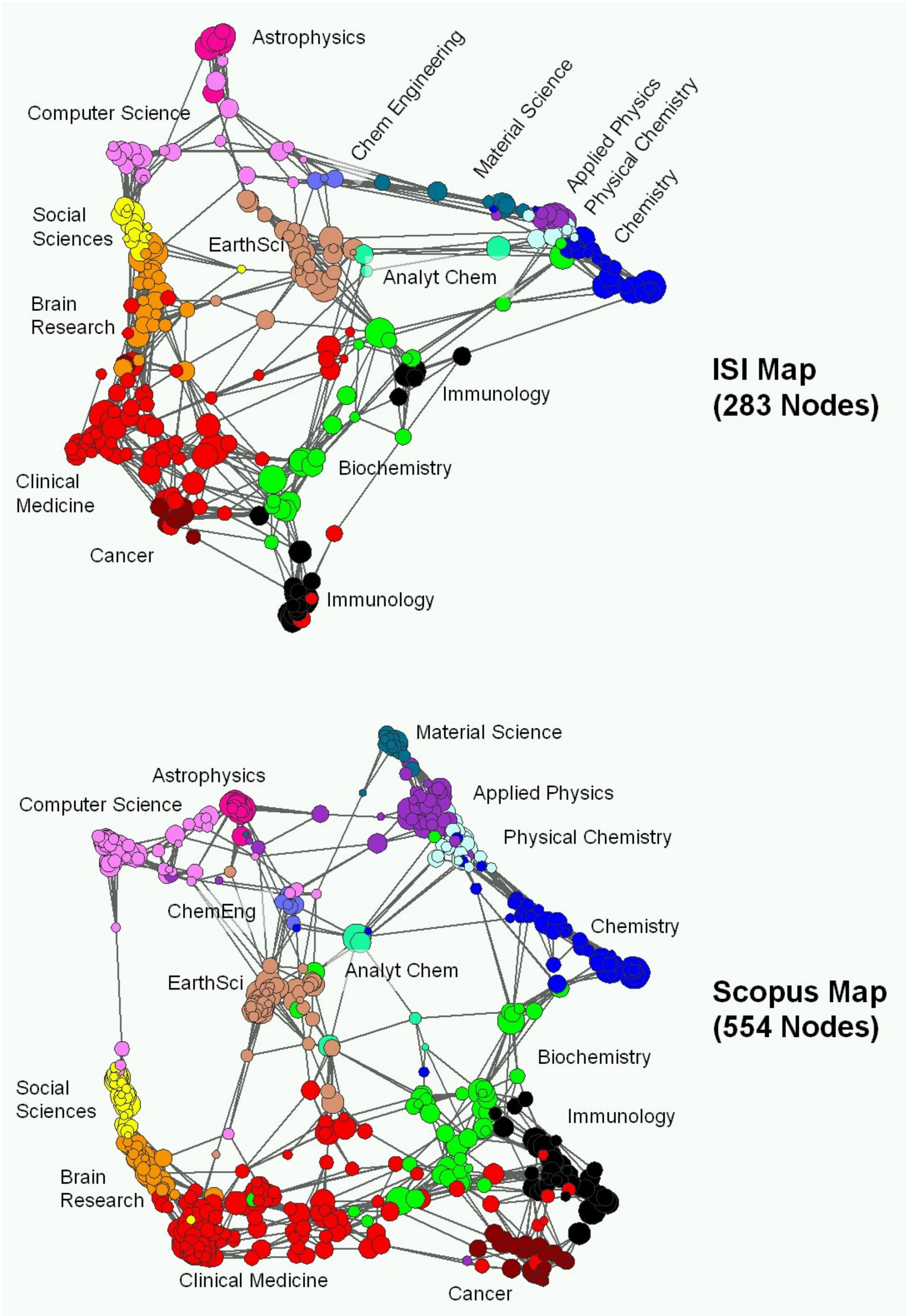

Figure 1. A comparison of the ISI and Scopus maps of science.

The ISI map has 283 nodes, while the Scopus map has significantly more (554 nodes). It is likely that several factors contributed to the Scopus map having twice as many nodes as the ISI map. First, there were 11% more reference papers in the Scopus database that met the co-citation threshold. In the absence of any other major differences, we would expect the Scopus map to have ~11% more nodes than the ISI map. Yet, there are other differences. Primary among these is the distribution of scientific vs. technical journals in the two databases. We expect that reference papers from technical journals tend to form smaller clusters than those from scientific journals. This may be so for several reasons – the technical literature 1) has fewer cites per paper, on average, than the scientific literature, 2) is more specialized and thus cites more of the periphery and less of the core scientific base, and 3) may cite more work from smaller journals than does a paper that is more scientific in nature. These factors combine to generate a reference map (the Scopus map) with significantly increased differentiation of the scientific literature.

In order to compare the maps more easily, we decided to split them up into multiple categories, so that the category sizes, shapes, and connections could be visually compared. Each map was divided into 15 different areas using a manual process of examining the paradigms, their dominant journal constituents, and the distribution of journals from current papers assigned to the paradigms. Each paradigm was manually assigned to one of the 15 categories.

The relative locations of disciplines that appear in the upper part of the map (*Computer Science, Astrophysics, Material Science, Applied Physics, Physical Chemistry, Chemical Engineering, Chemistry* and *Analytical Chemistry*) are shown in Figure 2. The first pair of maps in Figure 2 illustrates how the databases generate slightly different shapes and connections for *Computer Science*. The ISI database suggests that *Computer Science* is more connected and closer to the shape right below it (*Social Science*). The Scopus database suggests the opposite – *Computer Science* is more distant and less connected to *Social Science*, with a branch that is tightly linked to *Social Science* and a separate area that is located between *Clinical Medicine* and *Earth Science*. This difference may be due to the inclusion of proceedings. The ISI database does not include proceedings. The remaining journals in *Computer Science* have a strong relationship with *Social Science* (as shown on the left). The proceedings literature in *Computer Science*, which is significantly larger than the journal literature in *Computer Science* (Boyack, 2007; Glänzel, Schlemmer, Schubert, & Thijs, 2006), has a very weak and distant relationship with the *Social Sciences*. The Scopus Map illustrates the effect of adding these two literatures together. First, the proceedings literature links tightly with journal literature (as expected). But once combined, there is only a small section of *Computer Science* that is close to social science. The overall effect is to make these areas more distant from one another.

The shape and relative location of *Applied Physics* also differs significantly in the two maps. In Figure 2, the ISI map suggests that *Applied Physics* is a cluster of nodes that are separated from *Computer Science* and *Astrophysics* by *Chemical Engineering* and *Material Science*. The Scopus map suggests that *Applied Physics* plays a larger and more central role. There is a branch of *Applied Physics* that connects more directly to *Astrophysics*. *Material Science* appears on one side of *Applied Physics* (directly above), while *Chemical Engineering* appears off to one side. The differences in these two shapes seem to be a result of the inclusion of more journals and proceedings in *Applied Physics*, especially from Asia and the Far East. Greater coverage in *Applied Physics* results in morphological changes in the shapes shown in Figure 2.

Material Science, Applied Physics and *Physical Chemistry* also have different locations in the two maps. These disciplines are located along a line in upper right of the ISI map. The Scopus map, however, pulls out *Material Science* as a more distinct group, has a much larger domain for Applied *Physics*, and makes a wider separation between *Applied Physics* and *Physical Chemistry*. The remaining disciplines in the upper right part of these two maps – *Chemistry, Chemical Engineering* and *Analytical Chemistry* – are very similar in location and shape.

Figure 3 further illustrates how the maps are similar in the relative location of disciplines. All of the seven disciplines listed in this figure, which shows the lower portion of both maps, have the same relative placement. The only significant difference in location is *Cancer*. ISI places *Cancer* close to *Clinical Medicine*. Scopus suggests that *Cancer* is more differentiated and linked more tightly to

Immunology. There is also a significant difference in the shapes for *Immunology*. ISI generates two smaller shapes associated with *Immunology*, both of which are branched off of *Biochemistry*. The Scopus database shows a much larger and interconnected shape for *Immunology*.

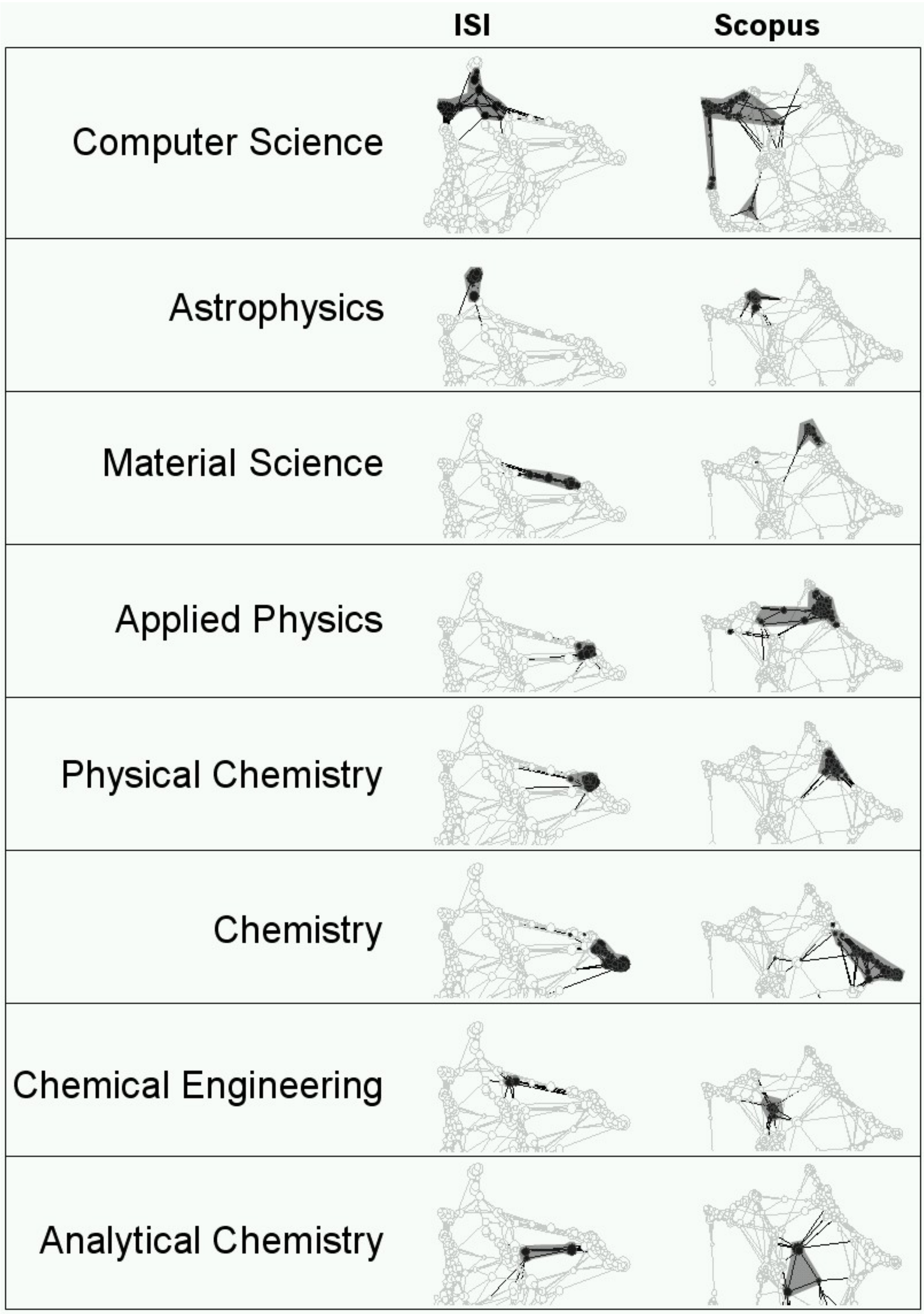

Figure 2. Locations and sizes of selected disciplines from the upper sections of both maps.

Additional research is needed to determine the reasons for the differences noted here. At this stage of the analysis, we suspect that the differences are due to aggregation and coverage. The more aggregated categories in the ISI map can easily hide the detail that would show relationships that appear in the Scopus Map. Disaggregating the larger nodes may help to reveal these relationships. We also suspect that lower coverage of an area of science will tend to result in a more distorted map; a greater coverage should reveal a more accurate picture of the shape and structure of science. The following section explores these issues more quantitatively.

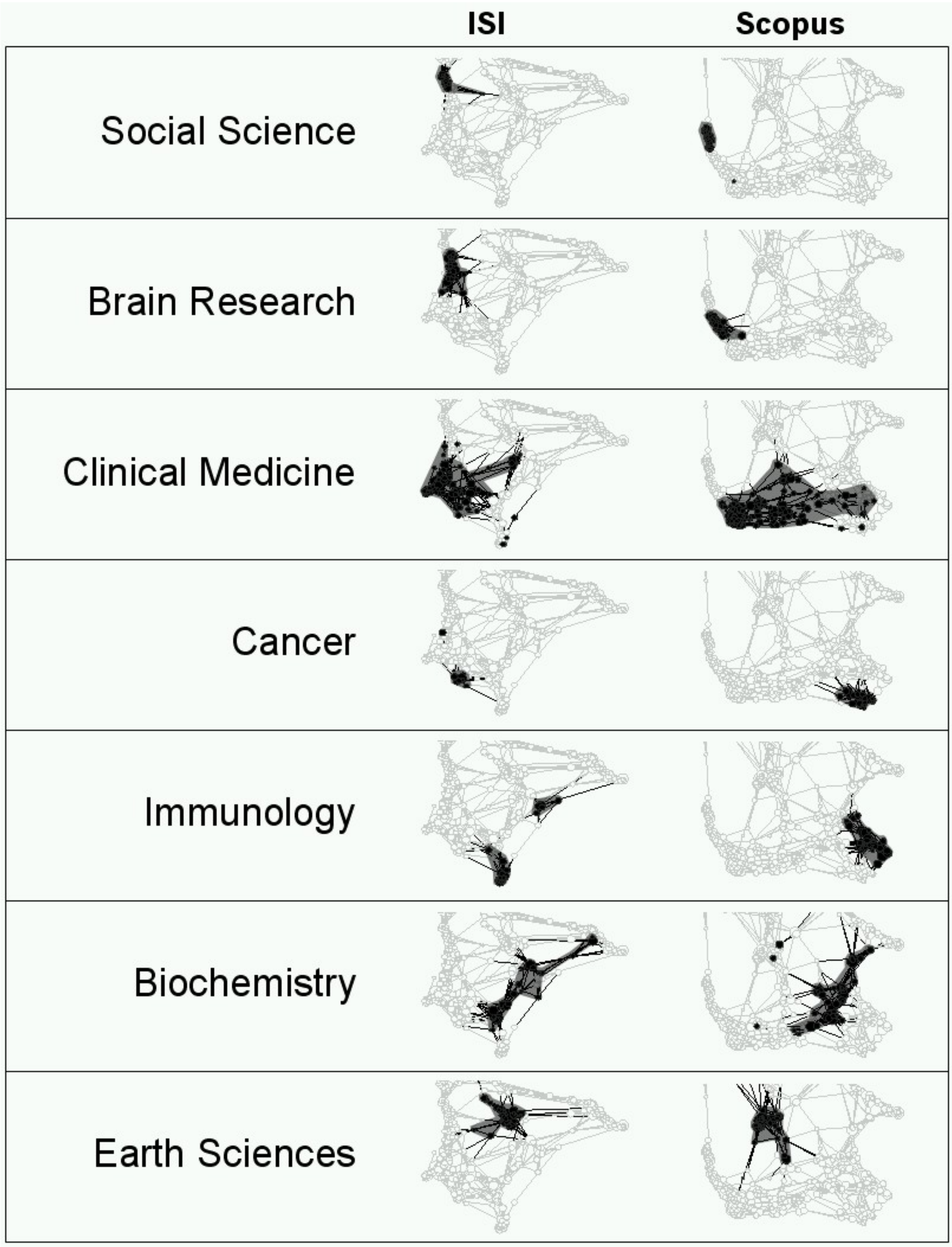

Figure 3. Locations and sizes of selected disciplines from the mid and lower sections of both maps.

Quantitative Analysis

As noted above, we based our study on data from two sources: ISI and Scopus. For the ISI map, we used the combined 2004 citation indexes (Science, Social Science, and Arts & Humanities) from Thomson Scientific. These databases cover approximately 9,000 journals, of which 8,408 were represented in the current paper assignments to our ISI paradigm map (see step 8 in the methodology section). However, these databases have only limited coverage of conference proceedings (especially proceedings in computer science). ISI is very restrictive in which journals they include in this database. Journals without sufficient evidence of scientific merit (such as the lack of a peer review procedure) are not included. While there may be controversies about the inclusion or exclusion of individual journals, there has been general consensus that the ISI database has a highly representative set of world-wide scientific literature.

It is important to note that ISI does have a separate Proceedings database that was not included in this study. There were two reasons for this exclusion. First, although the coverage of this database has been studied (Glänzel et al., 2006), it is not yet a standard procedure to include it in science maps. We are aware of only one instance in which the ISI Proceedings database has been included in a map of all of science (Boyack, 2007). The second reason is cost. The databases from ISI are costly, and there was not sufficient budget to include the Proceedings database in this study.

The 2004 Scopus database is larger. The number of titles (journals, proceedings, trade publications or book series) is far greater, over 14,000, of which 11,877 were represented in the current paper assignments to our Scopus paradigm map. The Scopus database was recently introduced into the marketplace and has not been subjected to the same critical analysis as the ISI database. We know relatively little about what it includes or excludes, except for claims and counter-claims in the press and a few preliminary comparisons (Jacso, 2005 and references cited therein).

We compared the ISI and Scopus journal coverage by matching journal titles between our ISI and Scopus science maps. The results shown in Figure 4 are preliminary, as we expect to find more matches over time, but are representative of the overlapping and unique coverage of the two data sources. Of the journals that are included in the current paper assignments in our models, there are 6,887 in common between the two sources. Thus, 82% of the ISI titles are covered by Scopus. Of the remaining 18%, nearly 10% are from the Arts & Humanities index, leaving only 694 science and social science journals that are not found in the Scopus model. Of the titles that are unique to Scopus, 3,910 are journal titles (based on information found at the Scopus website), and 1,080 are conference proceedings, trade publications, book series, etc. Two additional notes are in order. First, the overlap calculations are based on only those journals for which the databases have cited references. Scopus indexes approximately 1,400 Medline titles for which it does not have the cited references. Thus, those journals are not included in the Scopus map and overlap calculations. Second, the ISI Proceedings database typically indexes 1,200+ conference titles each year. We presume that there would be substantial overlap between the ISI and Scopus conference titles, at least among the larger conferences. If the ISI Proceedings database were added to our ISI map, it would likely balance out the conference coverage between the two models.

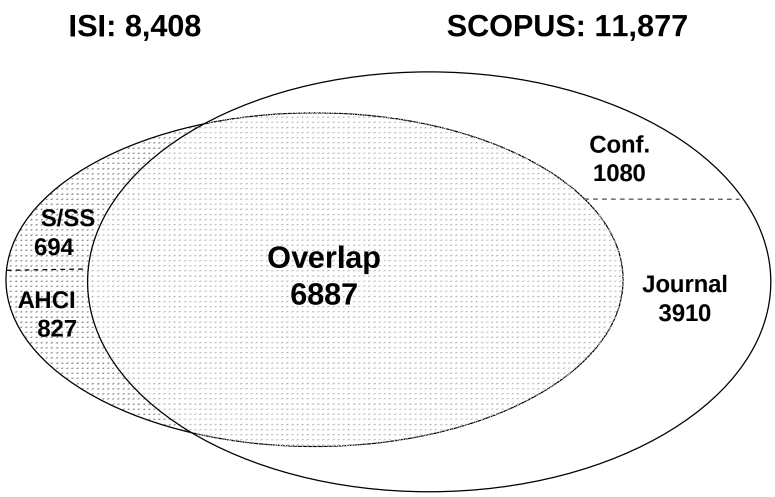

Figure 4: Overlapping and unique coverage of the ISI and Scopus databases for 2004. Only those journals included in the current paper assignments of our models are included in these numbers.

In addition to overall numbers of journals, Table 1 compares the numbers of journals and articles for the fifteen broad scientific areas shown in Figure 1. The areas where the ISI database has greater coverage are at the top, while the areas where the Scopus database is stronger are at the bottom. ISI has more journals and papers in two of fifteen areas of science: *Social Sciences* and *Astrophysics*. There are three areas in which the coverage is roughly comparable, more so in numbers of papers than journals: *Immunology*, *Chemistry*, and *Brain Research*. In the other ten areas, the Scopus database has substantially greater coverage. At the extreme is *Computer Science*, where the Scopus map has 816 more journals and 63,808 additional articles published in 2004 than the ISI map.

Table 1. Journal and current paper coverage for the Scopus and ISI models by scientific area.

Area	**Journals Scopus**	**Journals ISI**	**Diff (SC-ISI)**	**Current Scopus**	**Current ISI**	**Diff (SC-ISI)**
Social Sciences	2,338	2,350	-12	76,231	79,260	-3,029
Astrophysics	102	122	-20	29,777	30,102	-325
Immunology	569	434	135	72,760	71,516	1,244
Chemistry	427	360	67	69,250	67,135	2,115
Brain Research	747	655	92	66,140	62,829	3,311
Materials Science	465	261	204	32,121	27,360	4,761
Analytical Chemistry	88	70	18	15,959	11,185	4,774
Chemical Engineering	221	99	122	15,901	6,985	8,916
Earth Sciences	1,540	1,105	435	107,377	96,326	11,051
Applied Physics	371	266	105	83,680	69,403	14,277
Cancer	385	175	210	39,440	24,093	15,347
Biochemistry	556	357	199	77,639	55,151	22,488
Physical Chemistry	234	108	126	52,384	26,570	25,814
Clinical Medicine	2,181	1,209	972	206,818	165,115	41,703
Computer Sciences	1,653	837	816	135,739	71,931	63,808
All Areas	11,877	8,408	3,469	1,081,216	864,961	216,256

We have labeled the first area in Table 1 as *Social Sciences*. However, this means two different things in our two maps. In the ISI map, the majority of the Arts & Humanities journals and papers are located in the *Social Sciences* area. However, the Scopus map does not include any Arts & Humanities information. Since the two maps have nearly identical numbers of journals and papers in their *Social Sciences* areas, this suggests that the Scopus map has, in fact, greater coverage of the social sciences that is roughly equal in size to the Arts & Humanities portion of the ISI map. That the Arts & Humanities would cluster with the social sciences is not surprising given the category map of Moya-Anegón et al. (2004) showing arts, history, and philosophy as an appendage attached to the social sciences.

Table 2 compares the number of current papers and reference papers for the two maps shown in Figure 1. Here we introduce the concept of reference intensity, which is the number of reference papers per current paper in a particular area of the map. Reference intensity can be calculated at multiple levels. For instance, it can be calculated for each of the paradigms (283 in the case of the ISI map), or it can be calculated for the 15 areas of science identified in our maps.

Overall, the map based on the Scopus database has more current papers and references than the ISI database. The overall reference intensity (for the entire map) of the ISI data is higher. We suspect that reference intensity has an important impact on the aggregation of papers into paradigms. Higher reference intensity seems to result in greater aggregation (more links result in the algorithms deciding that there are fewer clusters). The difference in reference intensity may, in part, explain some of the structural differences noted in the previous section.

Table 2. Reference intensity for the Scopus and ISI models by scientific area.

Area	Refs Scopus	Refs ISI	Current Scopus	Current ISI	R/C Scopus	R/C ISI	Diff
Brain Research	179,162	56,590	66,140	62,829	2.71	0.90	-1.81
Astrophysics	73,731	41,746	29,777	30,102	2.48	1.39	-1.09
Chemistry	141,384	113,873	69,250	67,135	2.04	1.70	-0.35
Earth Sciences	237,687	190,873	107,377	96,326	2.21	1.98	-0.23
Clinical Medicine	485,165	384,014	206,818	165,115	2.35	2.33	-0.02
Immunology	183,074	181,258	72,760	71,516	2.52	2.53	0.02
Social Sciences	119,615	128,082	76,231	79,260	1.57	1.62	0.05
Analytical Chemistry	29,679	24,791	15,959	11,185	1.86	2.22	0.36
Physical Chemistry	90,937	64,236	52,384	26,570	1.74	2.42	0.68
Applied Physics	103,855	149,125	83,680	69,403	1.24	2.15	0.91
Computer Sciences	119,901	135,971	135,739	71,931	0.88	1.89	1.01
Biochemistry	200,249	207,510	77,639	55,151	2.58	3.76	1.18
Materials Science	33,173	62,810	32,121	27,360	1.03	2.30	1.26
Chemical Engineering	18,483	21,594	15,901	6,985	1.16	3.09	1.93
Cancer	83,336	131,077	39,440	24,093	2.11	5.44	3.33
All Areas	2,099,431	1,893,550	1,081,216	864,961	1.94	2.19	0.25

There is a significant variance in reference intensity for different areas of science, and the two databases do not agree on which areas have higher and lower reference intensities. (The correlation between the reference intensity for the two databases is not significant.) There does seem to be a tendency for a drop in reference intensity when additional current papers are covered. This suggests that the policy of focusing on a smaller set of highly linked documents will result in a smaller set of highly linked clusters (consistent with the ISI map). The policy to include more of the less-linked documents will result in an addition of smaller, less linked clusters (consistent with the Scopus map). Reference intensity may help to explain the structural differences in the two maps noted previously.

Table 3 shows another asymmetric pattern in journal coverage. We grouped journals according to the country associated with the publisher (using data from the Scopus web site). We then focused on two groups of nations: the major English-speaking nations (U.S., UK. and Australia) and Asia/Far East nations (16 nations – the largest being China, Japan, Russia, India, Singapore, Korea, Taiwan and Hong Kong). The overall pattern suggests that ISI focuses on journals that are published in the major English-speaking nations. Scopus has much better coverage of the journals where the publisher is located in Asia and the Far East. This pattern of geographic emphasis, however, is very sensitive to the area of science. Scopus' increased coverage of Asia/Far East journals is particularly apparent in *Chemical Engineering*, *Physical Chemistry*, *Materials Science* and *Cancer*. There are negligible differences in the percentages of *Applied Physics*, *Chemistry* and *Astrophysics* journals that are published in Asia/Far East. The actual number of journals published in Asia/Far East in these four areas, is roughly 30% greater due to the greater overall coverage of the Scopus database.

Table 3. Journal coverage by area and publisher location for the Scopus and ISI models.

Area	%English Scopus	%English ISI	Diff (SC-ISI)	%FarEast Scopus	%FarEast ISI	Diff (SC-ISI)
Social Sciences	82.16	86.86	-4.70	1.75	0.73	1.02
Brain Research	71.55	79.64	-8.09	3.21	0.91	2.30
Immunology	62.97	75.06	-12.09	5.64	2.64	3.00
Chemical Engineering	61.74	74.36	-12.61	17.45	2.56	14.89
Analytical Chemistry	65.38	71.19	-5.80	5.13	6.78	-1.65
Applied Physics	67.84	70.21	-2.37	16.47	15.74	0.73
Clinical Medicine	58.82	70.03	-11.21	8.68	4.03	4.65
Materials Science	61.76	69.96	-8.19	17.35	10.76	6.59
Cancer	56.79	69.82	-13.03	9.51	2.96	6.55
Biochemistry	62.35	67.67	-5.32	9.61	8.46	1.15
Computer Sciences	58.73	65.91	-7.18	12.21	6.98	5.23
Physical Chemistry	62.64	65.22	-2.57	20.11	13.04	7.07
Earth Sciences	54.86	64.19	-9.33	9.35	6.09	3.26
Chemistry	61.63	62.50	-0.87	14.83	15.71	-0.88
Astrophysics	54.55	55.34	-0.79	20.45	19.42	1.04

Summary

The maps presented in this paper are convergent in that there are no fundamental differences in the underlying structure of science. The relationships between basic areas of science remain quite similar. Any differences appear to be the result of coverage, reference intensity and aggregation. It appears that increased coverage (especially of proceedings and publications from smaller nations) lowers reference intensity, resulting in a more disaggregated map that more accurately describes how world-wide science is structured.

These findings, however, are limited. We do not know if maps of different time periods are sufficiently convergent that we can differentiate superficial changes (those based on the differences in coverage) from more fundamental changes (those reflecting underlying changes in the structure of science). Nor do we know if thematic maps (those built from clustering the current literature) are sufficiently convergent with paradigm maps (those built from clustering the reference literature) in a way that would enable differentiation of superficial relationships from more fundamental relationships. The existence of a convergent map that can be a shared cognitive framework for understanding the structure of science is still uncertain.

We argue, however, that this direction of research is extremely valuable, especially if there is continued evidence of convergence. Convergent maps can become a shared cognitive framework that, once learned, can provide the context for better understanding of divergent maps (e.g. maps of the same phenomena but with different layouts). An example may help to illustrate the importance of a convergent map. A map of the world, showing the location of continents and oceans, is an example of a convergent map. It is a shared cognitive framework that is quite adequate for most applications (world history, contemporary policy issues, etc.). While this is a shared framework that closely corresponds to one aspect of our world, one could argue that the map of the world is not adequate if one is interested in understanding continental drift. In this case, divergent maps (showing the initial land mass of Pangea and then the breakup of the continents might be more useful. Or, one could argue that the map is inaccurate if we were interested in population sizes or wealth. The world map has been redrawn to illustrate this phenomena. Each of these divergent maps, however, assume a core map that we are all familiar with and which, once learned and remembered, we can use as a framework for understanding the divergences.

Convergent maps of science can become a critical teaching aid. They can help us understand the intellectual neighbourhood in which we exist. They can help show the directions that a set of researchers are pursuing and point out fruitful directions for future research. They can provide fundamental insights into patterns of influence and expansion. And they can contribute to our basic understanding of how the shape and structure of science has changed over time.

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