Multiple dimensions of journal specificity: Why journals can't be assigned to disciplines

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Abstract

Journal classification systems have been used for many years for a variety of purposes. Many different such systems exist, a 'best' classification system has never been identified and there is a growing sense that a perfect journal classification system will never be found. We explore this question further by proposing and calculating four measures of journal specificity. We find that journal specificity has multiple dimensions. Assuming that disciplines are by definition more specific than broad, and that specificity has multiple dimensions, we suggest that few journals are truly disciplinary. This calls into question the validity of any journal-disciplinary classification system when used for research evaluation.

Introduction

Use of journal classification systems as a basis for search, comparison, or mapping of journals has a long history. Due to its incorporation into the Journal Citation Reports (JCR), the Thomson Reuters' (TR, formerly ISI) subject categories is perhaps the most well known and most used such classification system. Over the years many groups, including us, have generated their own journal maps or classification systems (Bassecoulard & Zitt, 1999; Boyack, Klavans, & Börner, 2005; Carpenter & Narin, 1973; Glänzel & Schubert, 2003; Katz & Hicks, 1995; Klavans & Boyack, 2010; Science-Metrix, 2010). Although most classification systems were originally created for search and retrieval or to better understand the structure of science, they are now being used for a different purpose – research evaluation. Many in the scientific and scientometrics communities continue to hope that a universally accepted classification system will one day be identified. However, as mentioned by Glänzel & Schubert (2003), it may be true that "after many centuries of constructive but yet inconclusive search for a perfect classification scheme, the only sensible approach to the question appears to be the pragmatic one: what is the optimal scheme for a given practical purpose?" Thus we continue to see many and new classification systems introduced; in fact two new systems were introduced in 2010 (Noyons, Waltman, Kähler, & van Eck, 2010; Science-Metrix, 2010) by prominent research groups. These classification systems are invariably used as the basis for evaluations, comparisons, rankings, etc., and different institutions and different types of research (i.e. disciplinary vs. interdisciplinary) are represented more or less well by different schemes.

Why might one expect there to be a best classification scheme? and conversely, why might one expect the opposite? On the one hand, as expressed by Leydesdorff & Rafols (2009), the journal-journal citation matrix seems nearly decomposable. However, 'nearly' is a key modifier in this respect, indicating that there are small numbers rather than zeroes in many places outside of the block-diagonal matrix structure. Furthermore, Leydesdorff & Rafols (2009) also note that many journals bridge disciplinary boundaries both in terms of their topical content and their reference structures. As additional evidence, in the TR subject category structure many journals are assigned to multiple categories.

The work presented in this paper was begun as an exercise to explore, and perhaps develop, potential indicators of journal specificity to complement existing journal indicators of impact

(Franceschet, 2010), research level (Narin, Pinski, & Gee, 1976), and interdisciplinarity (Leydesdorff & Rafols, 2011). Upon exploring the data we found that the multiple dimensions associated with journals provide a very strong argument that only some journals can be considered single-disciplinary. This fact, and other anecdotal evidence from applying journal classification systems for research planning and evaluation, has led us to the tentative and perhaps controversial conclusion that the use of a journal-based disciplinary classification system for research evaluation is fundamentally flawed. In the balance of this paper we describe the data and methods used, followed by an analysis of multiple journal dimensions leading to our conclusions.

Data and methodology

Data

The publication year 2008 data from Scopus, and the SciTech Strategies 2008 model (Klavans & Boyack, 2011) generated from those data were used for this study. The entire Scopus data were comprised of 1,885,278 individual records from 17,788 source titles (journals, proceedings, book series, etc. – hereafter referred to as journals), while only 1,479,574 articles appeared in the STS 2008 model. The primary reason that so many records do not appear in the model is that they have insufficient reference information; nearly 270,000 of the Scopus records have no references (presumably these are not supplied to Scopus by publishers), and another 82,000 have fewer than 5 references. In addition, nearly 280,000 (14.8%) of the Scopus records have no abstract.

Regarding the 2008 STS model, it is comprised of 1,479,574 articles (published in 2008) clustered into 97,276 research communities. Clustering is based on co-citation analysis. Although articles can be fractionally assigned to research communities based on references, in this study we assign each article singly to its dominant community. Details of the model building methodology are provided in Klavans & Boyack (2010, 2011).

Our analysis was limited to those journals with articles in the STS 2008 model, and for which there were abstracts, namely to 15,612 journals containing 1,512,142 articles with abstracts and 1,467,160 articles appearing in the model.

Journal specificity measures

In an attempt to measure journal specificity, we identified four quantities that might serve as indices. One was based on textual coherence of the titles and abstracts of journal articles, and the other three are all based on features of the 2008 STS model.

<u>*Textual coherence:*</u> Textual coherence was investigated as a measure of journal specificity under the assumption that journals covering a very limited set of topics would have high coherence, while those covering a large, and possibly multidisciplinary, set of topics would have low coherence.

Textual coherence for each journal was calculated using the Jensen-Shannon divergence (JSD) as specified and used in Boyack & Klavans (2010), but where each cluster is comprised of the documents from a single journal. JSD quantifies the distance (or divergence) between two probability distributions. It is calculated for each document from the word probability vector for that document, and from the word probability vector for the cluster (in this case, journal) in which the document resides as:

$$JSD(p, q) = \tfrac{1}{2} D_{KL}(p, m) + \tfrac{1}{2} D_{KL}(q, m)$$

where $m = (p+q)/2$ and $D_{KL}(p, m) = \sum (p_i \log (p_i/m_i))$

and p is the frequency of a word in a document, q is the frequency of the same word in the cluster of documents, and D_{KL} is the Kullback-Leibler divergence. JSD is calculated for each journal as the average JSD value over all documents in the journal.
JSD is a divergence measure, meaning that if the documents in a journal are very different from each other, using different sets of words, the JSD value will be high. Journals containing documents with similar sets of words – a less diverse set of words – will have a lower divergence. JSD also varies with the number of documents – larger journals will naturally be more divergent than smaller journals. We normalize for this by calculating JSD for random samples. The coherence value for journal i with n documents is defined as:

$$Coh_{i,n} = JSD(rand)_{i,n} - JSD(actual)_{i,n}$$

where *JSD(rand)* is the random divergence for a journal with n documents.

Radius: Various features calculated from the STS model of science can be displayed on the circle of science, which is based on a high-level consensus map generated from 20 detailed maps of science (Klavans & Boyack, 2009). The circle of science is a layout system around which research communities are ordered (Klavans & Boyack, 2010). Since each document is assigned to one or more research communities in the model, and each research community has a position on the edge of the circle, the position of any set of documents relative to the circle can be calculated as the average position of those documents. The circle has been used to show the positions of university and country competencies (Klavans & Boyack, 2010) and is used in this study to show the positions of journals. Given a unit circle, the radius, or distance from the center of the circle of a journal can be used as a measure of its specificity. Journals with a radius of close to 1.0 can be thought of as very specific in terms of their topical breadth, while those with smaller radii, and thus closer to the center of the circle, are comprised of more disparate topics and thus have broad coverage.

Community leadership: Each of the 97,276 communities (or topical clusters of articles) is populated by articles from a particular set of journals. A journal ranking can be generated for each community, thus allowing us to list the set of community rankings for each journal. For example, a journal may have articles in 50 communities, be ranked first in 2 of those communities, and be ranked in the top5 journals in 10 of those communities. We propose a measure of journal specificity based on its distribution of community rankings. If a journal has articles in few communities and has a high ranking in most of those communities, then the journal is topically focused, a leader in those topics, and can be considered highly specific. Conversely, if a journal has articles in many communities, and is a leader in none or few of those, the journal can be considered to have broad topic coverage. For each journal we have calculated a measure of community leadership as:

$$RCL = (n_1 + n_5/20) / N$$

where n_1 and n_5 are the number of communities in which the journal ranks #1 and in the top5, respectively, and N is the number of communities in which the journal has articles. Thus, this measure rewards being the top ranked journal in a community as well as being within the top5 ranked journals in a community. We note that the formulation of this indicator is arbitrary – #1 rankings have an effective weight of 1.05, while ranks #2-5 have weightings of 1/20. We intentionally weighted #1 rankings much higher than the others. Different formulations and weighting schemes could certainly be explored.

Concentration: Our measure of concentration is similar to the measure of community leadership, but considers more than just top5 rankings. It assumes that if a journal's contents are concentrated in just a few communities and make up a large fraction of the contents of those communities, then the journal is specific. We calculate concentration for each journal J using the Herfindahl measure as:

$$Herf_J = \sum (n_{i,J} / n_i)^2$$

where $n_{i,J}$ is the numbers of articles from journal J in community i, and n_i is the total number of articles in community i, summed over all communities in which the journal has articles.

Transforms: Although each of the journal specificity measures introduced here fall between zero and one for all but a few cases, their distributions are highly skewed. We thus applied logarithmic transforms to the *Coh*, *RCL*, and *Herf* values to create index values ranging between zero and one in distributions that were much closer to linear. The specific transforms used were:

$$Log (Coh) = (Min(Max(Log(Coh) + 2, 0.3), 1) - 0.3) / 0.7$$
$$Log (RCL) = Min(Max(Log(RCL) + 2.5, 0), 2) / 2$$
$$Log (Herf) = Min(Max(Log(Herf) + 2.5, 0), 1.5) / 1.5$$

and the resulting distributions are shown in Figure 1. The log transformed index values for these measures were used for all of the comparisons that will be shown hereafter. We attempted to transform (*1-Radius*) using a function similar to that for *RCL*, but it made very little difference to the curve; thus, a log transform for *Radius* was not used. Note that all four of the indices shown in Figure 1 are designed to denote breadth at their low end (0) and specificity at their high end (1). Thus, we would expect these four measures to be positively correlated with each other.

Additional measures

Journal specificity is certainly not the only dimension that should be explored in a study of the utility of journal classification. Thus we added several existing measures to our list before proceeding with the analysis:

- journal size (number of articles),
- CWTS/Scopus source normalized impact-per-paper (SNIP) measure (Moed, 2010),
- SCImago journal rank (SJR) (Gonzales-Pereira, Guerrero-Bote, & Moya-Anegón, 2010), and
- CHI research level (Res Lev).

It is often wise to include size in an analysis since it tends to explain so many things in simple bibliometric distributions; thus, we included it here. We also added two impact measures (SNIP and SJR) to see if any of our proposed measures might correlate with them. SNIP and SJR measures for 2008 were available for 14,050 of the journals in our study.

Narin et al. (1976) introduced a set of four research levels for biomedical literature ranging from basic to applied, and assigned levels to each of 900 biomedical journals. CHI later broadened the level descriptions to include fields outside biomedicine. These research levels are still used today in the biannual Science and Engineering Indicators reports (cf. National_Science_Board, 2008). The four research levels, along with their descriptions specific to biomedicine and in general, respectively, are:

(1)	Clinical observation	Applied technology
(2)	Clinical mix	Engineering-technological science

(3)	Clinical investigation	Applied research
(4)	Basic research	Basic scientific research

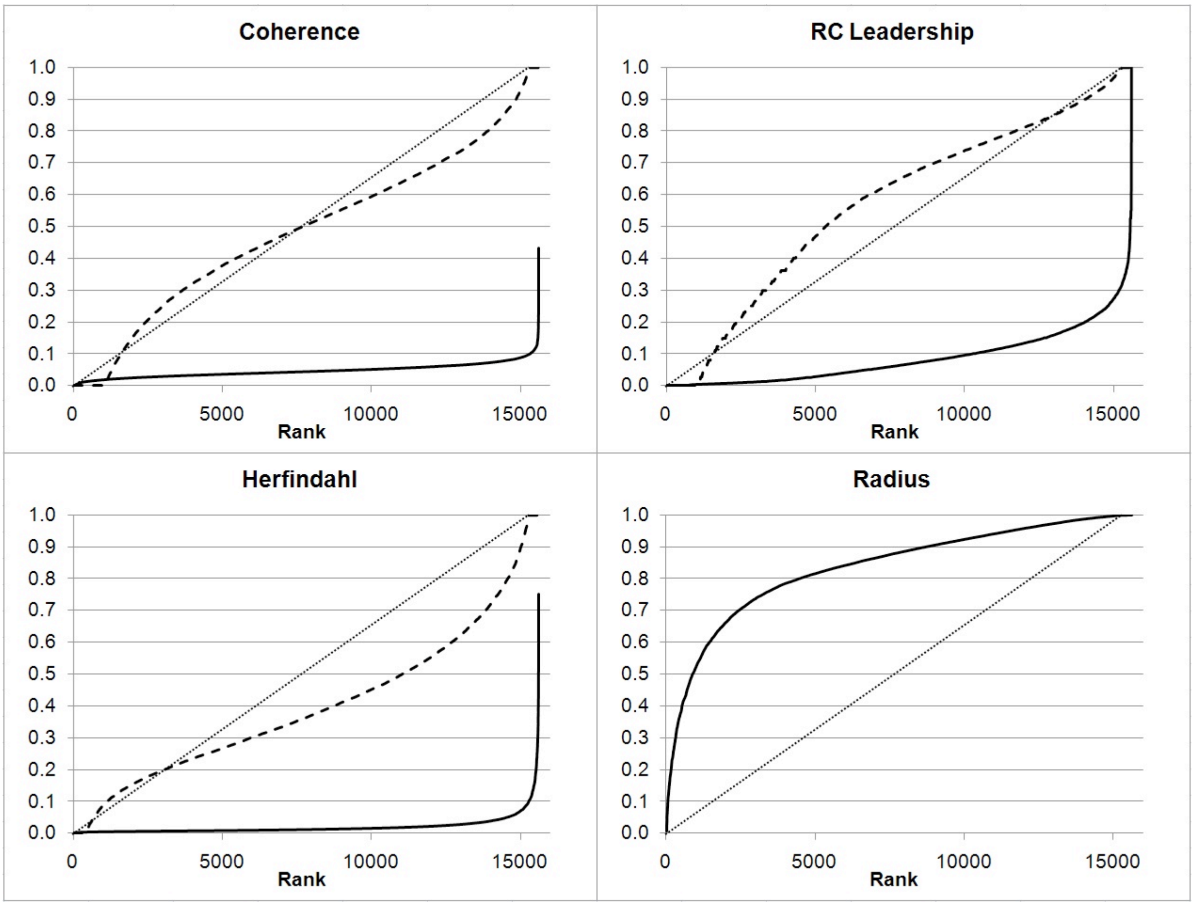

Figure 1. Values of journal specificity as a function of rank. Raw values are shown as solid lines, while the log transformed values are shown as dashed lines.

We were able to assign research levels to 4,046 journals by matching Scopus journal names to the NSF journal list (obtained from Lawrence Burton, NSF/SRS, February 2008). Although one cannot equate the notions of 'broad vs. specific' and 'basic vs. applied', our intuition was that there might be some correlation between them.

Results

As mentioned above, we expected that our four new journal specificity measures would be positively correlated, perhaps highly so. We also expected that the journals with broad coverage might be those that are more basic in terms of research level, and that journals with very specific coverage might be more applied. If this is the case, then research level should be negatively correlated with our four new measures, since research levels go from applied to basic (1-4), while our specificity measures go from broad to specific (0-1). Regarding size, we expected that small journals would be more specific, and that large journals would have broader coverage. If this is true, size should be negatively correlated with the journal specificity measures. Regarding the impact measures, we saw no reason to expect any correlation between them and journal specificity.

We tested the above hypotheses by calculating correlation coefficients (Pearson's r) between pairs of measures (see Table 1). We first note that our four new journal specificity measures are positively correlated, as expected, but that these correlations are not large, with one exception. Community leadership (*Log(RCL)*) and concentration (*Log(Herf)*) are highly correlated (0.644), suggesting that these two measures are similar enough that both are not needed; they do not describe independent dimensions of specificity. However, the other correlations within this set are all small enough (<0.21) to suggest that journal specificity is not adequately described by a single dimension, but may have three separate components. We thus limit further discussion of journal specificity to three measures – radius, coherence, and concentration.

Table 1. Correlation (Pearson's r) between journal measures.

	Size	*SNIP*	*SJR*	*Res Lev*	*Radius*	*Log(Coh)*	*Log(RCL)*
Size							
SNIP	0.1249						
SJR	0.1258	0.4701					
Res Lev	0.0921	-0.0594	0.1578				
Radius	-0.0228	0.0791	-0.0182	-0.0400			
Log(Coh)	-0.0391	0.1227	0.0212	-0.2702	0.2085		
Log(RCL)	0.1825	0.2085	0.0497	-0.0134	0.0556	0.1265	
Log(Herf)	0.1973	0.0792	0.0267	0.1182	0.0480	0.1463	0.6440

Regarding research level, as expected there is a small negative correlation between it and coherence (-0.27). However, there is no correlation between research level and radius, and a surprising small positive correlation between research level and concentration. We expected size to be correlated with specificity, but found that there is very little correlation between the two. Specifically, there is no correlation at all between size and radius, or between size and coherence. There is a small positive correlation (0.197) between size and concentration; larger journals are actually more specific than smaller journals in the sense that their content is concentrated, which is a counterintuitive finding. Size is also slightly positively correlated with the two impact measures. There are also small positive correlations between the impact measures and the specificity measures (e.g., *SNIP:Log(Coh)* at 0.123). However, these are all small enough that we feel no need to investigate further.

Figure 2 shows the positions of all 15,612 journals within the circle of science. Each journal is represented by a node whose size reflects the size of the journal, and whose shade (grayscale) reflects the journal's coherence (top) or concentration (bottom). Radius can be inferred by distance from the center of the circle. Note that *Science* and *Nature* are where one might expect them to be – closer to the center of the circle than to the edge, and midway along the arc reaching clockwise from Chemistry to the Medical Specialties.

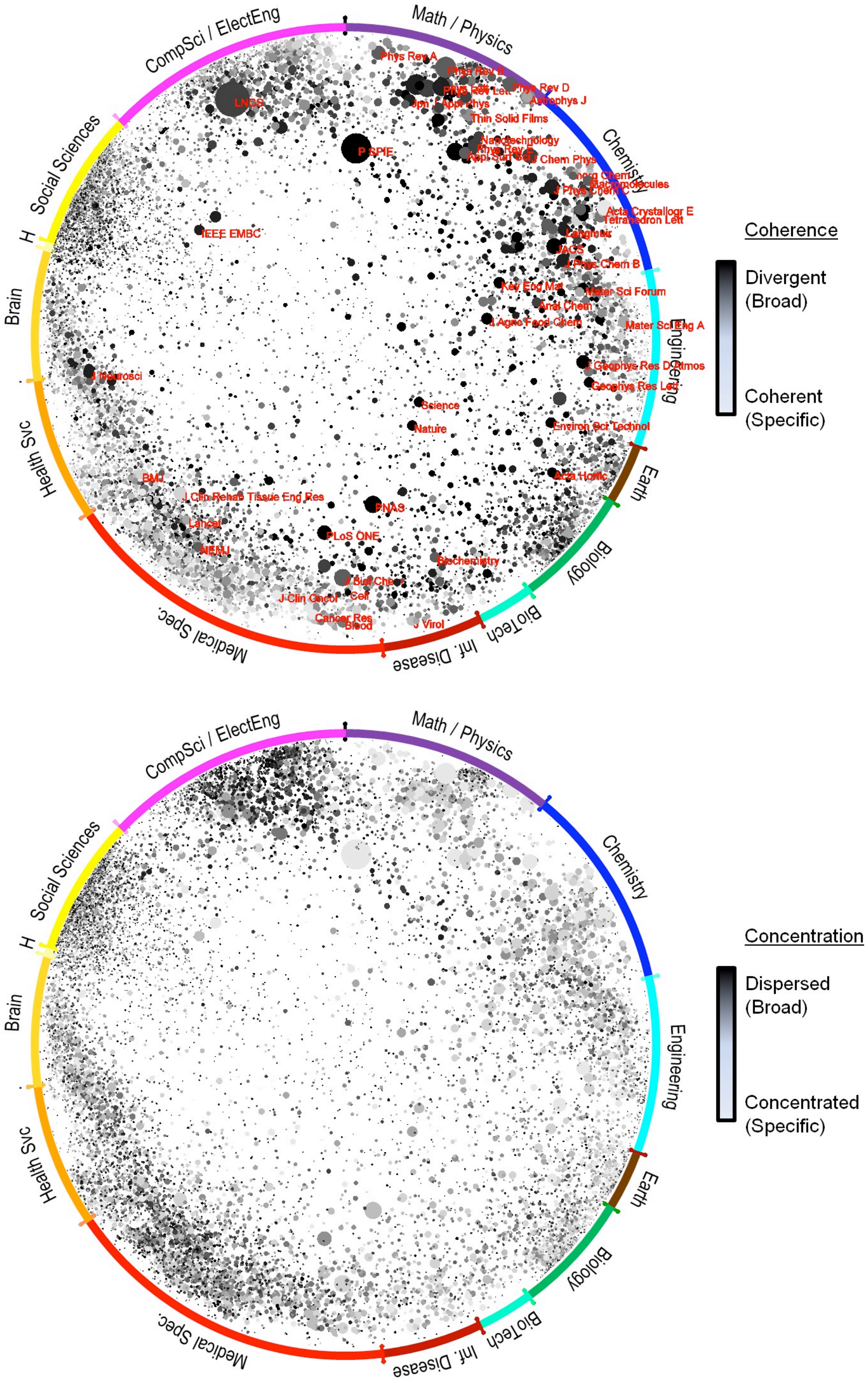

Figure 2. Journal positions within the circle of science. Node size indicates the number of articles (PNAS=3500, Nature=1160). Node shading indicates coherence (top) or concentration (bottom).

A number of very interesting observations about journals and their dimensions can be gleaned from close inspection of Figure 2. Although not a focus of this study, perhaps the first thing one sees is that journal size is extremely field-dependent. This was noted recently by Franceschet (2010) in tabular form, but the effect is dramatic in visual form. The majority of large journals are found in Physics and Chemistry. The Computer Science, Engineering, Earth and Biological Sciences seem to have a distribution of journal sizes, many of medium size. The medical areas are composed of mostly small-to-medium sized journals, with a few large journals, and the Social Sciences are almost entirely comprised of small journals.

Most large journals are not close to the center of the circle, but are rather in a radius band between 0.80-0.95, suggesting that they may be multidisciplinary in a broad field type of sense (e.g., broad across Physics or Chemistry). However, there are a few large journals that are very close to the edge (e.g., *Phys Rev D*, *Astrophys J*), and thus appear to be disciplinary from that perspective. There is a distinct lack of journals very near the edge of the circle in Chemistry, Biotechnology, and in parts of Medical Specialties, Health Services, and Mathematics, indicating that these broad fields may in some way be inherently more multidisciplinary than those broad fields such as Computer Science and the Social Sciences that have many journals near the edge of the circle.

Although one might expect small journals and those close to the edge of the circle to be very topically coherent, a surprising number are topically broad (dark nodes), especially in the social sciences.

The two images in Figure 2 have interesting points of contrast – some areas of the circle have light nodes in one image and dark nodes in the other. For example, most of the large journals (those that are labelled and those of similar size) are broad in terms of their topical coverage (coherence – dark nodes), yet are specific in terms of their topical focus (concentration – light nodes). In other words, these journals seem to cover a diverse set of topics, and at the same time attract a large number of articles in that set of topics. The so-called hard sciences, from Mathematics clockwise around the circle to Biology, exemplify this behavior in general – low topical coherence and high concentration within topics.

Journals in the Medical Specialties seem to show the opposite effect; many of them have high topical coherence (light nodes), but are not concentrated in terms of the communities they populate (dark nodes). This is a very interesting combination, and suggests that topical differentiation between communities in medicine may be less distinct than in the physical sciences. We leave this to further testing and discussion. To more fully understand these data we need a better understanding of the notions of topical coverage and topical focus, along with their overlaps and differences.

There are obviously large differences between journal specificity measures (radius, coherence, concentration) at the individual journal level; the correlation coefficients suggest multiple dimensions. Each of these dimensions is intended to be an index along the broad-to-specific continuum in terms of topic space. Given that there appears to be these multiple dimensions along which disciplines can be defined, and given that disciplines are assumed to have boundaries, each discipline comprised of a set of topics with some (but not too much) overlap, we suggest that those journals that are single-disciplinary are those with high index values in all three dimensions. A difficulty arises in the setting of thresholds for each index denoting 'what is disciplinary'. Thus we have calculated the numbers of journals with high index values in all three dimensions using three different thresholds – those in top quarter (highest 25%) for each index value, those in the top half (highest 50%) for each index value, and those in the highest 75%.

Table 2 shows the index values for each measure at each of the three threshold values, along with the number and fraction of journals that meet the thresholds at each level. If one assumes that half of the journals are single-disciplinary along a particular dimension (highest 50%), then only 16.0% of the journals are single-disciplinary overall. This points out the difficulty of unambiguously assigning journals to disciplinary categories if there are multiple dimensions of disciplinarity. Note that the actual values are slightly higher than the expected values if the three distributions were random. For example, using the highest 50% case, one would expect $0.5^3 = 0.125$ (12.5%) of the journals to meet the threshold if the measures were fully independent or randomly distributed. The actual values are higher than the randomly expected values because of the positive, but small, correlations between dimensions.

Table 2. Numbers of journals meeting different thresholds for all three journal specificity measures.

	highest 25%	*highest 50%*	*highest 75%*
Radius	0.9536	0.8824	0.7825
Log(Coh)	0.6710	0.5040	0.3146
Log(Herf)	0.5362	0.3631	0.2311
# Journals	405	2491	7166
% Journals	2.6%	16.0%	45.9%
% Expected	1.6%	12.5%	42.2%

We did not calculate the numbers of journals that could be considered disciplinary along at least one dimension, but do show how some journals known to the bibliometrics community differ along those dimensions (see Table 3). Using the highest 50% threshold, *Information Processing & Management* and *Library & Information Science Research* would be single-disciplinary across all three dimensions. *Journal of Documentation*, *JASIST*, and *Scientometrics* would each be single-disciplinary across two of the three dimensions, but differ in the pairs of dimensions represented. *Journal of Information Science* is not single-disciplinary in any of the three dimensions. By contrast, both *Science* and *Nature* could be considered disciplinary in terms of concentration; despite their known topical diversity and the fact that they are assumed by nearly everyone to be multidisciplinary journals.

Table 3. Journal specificity measures for certain journals. Bolded and shaded cells are those in which the journal is within the highest 50%.

	radius	*log(coh)*	*log(herf)*
Inf Proc Mgmt	**0.956**	**0.535**	**0.522**
J Doc	**0.905**	**0.966**	0.183
J Info Science	0.863	0.415	0.093
JASIST	**0.888**	0.200	**0.444**
Libr Inf Sci Res	**0.949**	**0.524**	**0.376**
Scientometrics	0.852	**0.631**	**0.576**
Nature	0.363	0.000	**0.455**
Science	0.322	0.000	**0.509**

Limitations

We note that there are limitations to this study. As mentioned above, despite the fact that we have introduced three indices of journal specificity, we do not fully understand what they measure. We do not fully understand how these measures relate to disciplinarity. Our radius index is dependent upon the circle of science and the STS model of science, and upon how research communities are ordered around the circle. Although the exact ordering can be called into question, we are certain that a reordering done using another protocol would produce very similar results in the aggregate given the overall similarities of many recent maps of science at the global level (Klavans & Boyack, 2009; Rafols & Leydesdorff, 2009).

Conclusions

Disciplinary categories have been used for decades to facilitate search and retrieval. Even in the modern era, subject categories at ISI were first considered by Gene Garfield as 'convenient buckets' in which to place different journals (Henry Small, personal communication, January 12, 2011). Many studies (as referenced in the introduction) have effectively explored the structure and complexity of science using journal categories. The notion of disciplinary categories and the assignment of journals to these categories have been (and still are) extremely useful for these purposes.

The use of disciplinary categories as the basis for research evaluation is a much more recent development. Rather than being 'convenient buckets' for search and retrieval, these categories have become a self-justification for the existence of disciplines and definition of disciplinary boundaries, and are used to rank nations, institutions, and even departments. Although many researchers realize that defining disciplines using groupings of journals is a simplification with significant error and overlap (Boyack et al., 2005), the notions of disciplines and disciplinary boundaries remain the basis for most research evaluation. We suggest that the application of journal-based disciplinary boundaries for research evaluation is dangerous at best (Klavans & Boyack, 2010).

It is well known that some journals are much more difficult to classify than others. In this study we set out to investigate several indices of journal specificity under the (perhaps naive) assumption that they would strongly correlate, and that a useful composite indicator of journal specificity could be introduced. We were surprised to find multiple dimensions of specificity. There is far more that we need to learn and understand about what each of the journal specificity indices in this study is actually measuring. However, it does seem clear that there are multiple dimensions and thus multiple ways to define disciplines and disciplinarity. The existence of these multiple dimensions calls into question the use of disciplinary classification systems and disciplinary boundaries *as the basis for science metrics*. (By contrast, it does not call into question the use of journal categories for search and retrieval.) Although we agree with Glänzel & Schubert (2003) that disciplinary classification systems designed to meet particular purposes are currently better than any single so-called 'best' system, we suggest that more accurate metrics may only be achievable with classification systems based on articles rather than journals.

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