A Reproducible Journal Classification and Global Map of Science

Based on Aggregated Journal-Journal Citation Relations

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Abstract

A number of journal classification systems have been developed in bibliometrics since the launch of the Citation Indices by the Institute of Scientific Information (ISI) in the 1960s. The best known system is the so-called “Web-of-Science Subject Categories” (WCs). Each system has its own advantages and disadvantages. Using the Journal Citation Reports 2014 of the Science Citation Index and the Social Science Citation Index (n of journals = 11,149), we examine the options for developing an unambiguous classification of the journals into subject categories on the basis of aggregated journal-journal citation data. Combining routines in VOSviewer and Pajek, a tree-like classification is developed which can be reproduced unambiguously. At each level one can generate a map of science for all the journals subsumed under the category. Nine major fields are distinguished at the top level, with the social sciences as a single field (n of journals = 3,131). In this study, further decomposition of the social sciences is pursued for the sake of example with a focus on journals in information science (LIS) and science studies (STS). The classification improves alternative options by removing subjective judgement and avoiding the problem of randomness in the seed number that has made algorithmic solutions hitherto irreproducible. A non-subjective map and classification can provide a baseline for measuring the effectiveness of policy interventions. Maps can be compared between years, and change in the (social) sciences can be indicated.

Keywords: classification, subject categories, disciplines, citation, journal

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1. Introduction

During the last decade, the landscape of journals has changed dramatically. Open access and predatory publishing are shifting the markets. These changes may have consequences for journal mapping and journal classification. *PLoS ONE*, for example, has grown since 2007 as a scholarly journal across the disciplines; in 2014, *PLoS ONE* published more than 30,000 papers and has become by far the largest journal in the Web of Science (WoS). In 2004, *Google Scholar* and Elsevier’s *Scopus* encroached on the monopoly of the Institute of Scientific Information (ISI) of Thomson Reuters that has provided the academic community with citation indexing, impact factors, and journal categories since the 1960s. The spectacular growth of *PLoS ONE* as a transdisciplinary journal—with an emphasis on quality control of methods rather than topical importance—has been followed as a business model by similar journals such as *Nature Communications* (2010), mimicking also the trans-specialistic role of *Chemical Communications* (since 1996; but within the discipline of chemistry).

These developments have led to stronger engagements in quests for journal categories among bibliometricians, for example, for the purpose of normalizations in evaluation studies—but also for the purpose of a better understanding (if not explanation) of how the sciences develop in terms of disciplines and inter-disciplines. Elsevier’s *Scopus* introduced the SNIP indicator as an alternative to ISI’s impact factor; SNIP is largely independent of structural assumptions about disciplines and specialties because fields are defined in terms of the citing papers (Moed, 2010). Researchers at the Center for Science and Technology Studies in Leiden (CWTS) went one step further and proposed clustering the WoS at the level of documents as an alternative to journal
classification and mapping. However, the 4000+ resulting clusters are irreproducible and cannot easily be validated (Klavans & Boyack, 2015; Leydesdorff & Bornmann, 2016). Thus, it is impossible to designate changes between years.

For the intuitive understanding, a reproducible classification on the basis of journals would remain most useful for both journal evaluations and the evaluation of S&T policy interventions. Ideally, a classification should be coupled to maps of the sciences at different levels of granularity (Zitt et al., 2005), so that one would be able to zoom in and out in order to distinguish among fields of science (e.g. engineering), sub-fields (e.g., transport), disciplines, sub-disciplines (e.g., inorganic chemistry), and core specialties that carry community functions such as annual meetings and specialist journals (e.g., organo-metallic chemistry). The designation and labeling do not follow from the algorithms, but are part of the semantics that we as analysts bring to the data. Although any classification remains a simplification of the network-like structures under study, it may improve on existing classification schemes, such as the Web-of-Science (WoS) Subject Categories which are frequently used in bibliometric evaluations.

A number of journal classification systems have been developed since the launch of the Citation Indices by the Institute of Scientific Information (ISI) in the 1960s (Elkana et al., 1978; Garfield, 1979a). The Citation Indices (Science Citation Index, Social Science Citation Index, and Arts & Humanities Citation Index) are based on the lists of journals included (Garfield, 1972). The inclusion criteria are not fully transparent (Testa, 2003), but citation plays a central role (McVeigh, personal communication, 9 March 2006; cf. Leydesdorff, 2008). Since citation practices differ among fields of science, one would be “comparing apples with oranges” in
transdisciplinary citation analysis without prior normalization and field delineations. For this purpose ISI tags the journals with the so-called ISI Subject Categories that were renamed “Web-of-Science Subject Categories” (WC) with the introduction of version 5 of the WoS in 2009 (Leydesdorff, Carley, and Rafols, 2013). Unlike the alternative classification developed since 1972 by Computer Horizon’s Inc. for the Science & Engineering Indicators series of the NSF (Carpenter & Narin, 1973; Narin, 1976; Narin & Carpenter, 1972), more than a single WC can be attributed to each journal in WoS.

The approximately 250 WCs are assigned by ISI staff on the basis of a number of criteria including the journal’s title and its citation patterns (Bensman & Leydesdorff, 2009). Pudovkin and Garfield (2002) described the method used for assigning journals to WCs, as follows:

This method is “heuristic” in that the categories have been developed by manual methods started over 40 years ago. Once the categories were established, new journals were assigned one at a time. Each decision was based upon a visual examination of all relevant citation data. As categories grew, subdivisions were established. Among other tools used to make individual journal assignments, the Hayne-Coulson algorithm is used. The algorithm has never been published. It treats any designated group of journals as one macrojournal and produces a combined printout of cited and citing journal data. (p. 1113n.)

According to the evaluation of Pudovkin and Garfield (2002), in many fields these categories are “sufficient”; but “in many areas of research these ‘classifications’ are crude and do not permit the user to quickly learn which journals are most closely related” (p. 1113). Boyack et al. (2007) estimated that the attribution is correct in approximately 50% of cases across the file (Boyack,
personal communication, 14 September 2008). Leydesdorff & Rafols (2009) found that the WC can be used for statistical purposes at high levels of aggregation, but not for detailed evaluations. In the case of interdisciplinary fields, problems of imprecise or potentially erroneous classifications can a fortiori be expected (Rafols et al., 2012).

In bibliometric evaluations, journals are often attributed percentages proportional to the categories under which they are subsumed. These multiple categories have also been considered as indicators of the interdisciplinarity of journals (Bordons et al., 2004; Katz & Hicks, 1995; Morillo et al., 2001). However, different categories may cover rather similar sets of journals, for example, in the domain of biomedicine (Rafols & Leydesdorff, 2009, p. 1830). In other cases, the categories added by an indexer can generate relations among otherwise unrelated journals. This can be useful for purposes of information retrieval, but blurs the analytical distinctions.

Notwithstanding these problems, WCs have become the basis for bibliometric evaluation studies. Braun, Schubert, and Glänzel introduced the normalization of citations in terms of journal categories—as proxies of scientific fields defined above the level of individual journals—in a series of publications during the 1980s (e.g., Schubert et al., 1986; 1989; Vinkler, 1986). Moed et al. (1995) further developed the so-called “crown indicator” of the Center for Science and Technology Studies (CWTS) in Leiden, arguing for field-normalized citation counts as outperforming normalization at the level of journals. The crown indicator was later improved as the “Mean Normalized Citation Score” (MNCS), but this indicator is based on the same subject categories (cf. Leydesdorff & Bornmann, 2016; van Eck et al., 2013).\(^4\)

\(^4\) As noted, this indicator was since 2014 replaced in the Leiden Rankings with clusters at the document level.
The use of these journal categories has become accepted as “best practice” among bibliometricians (e.g., Rehn et al., 2014). For example, InCites—a customized, web-based research evaluation tool developed by Thomson Reuters—routinely provides normalizations of citation impact using WCs for the delineation of the reference sets (e.g., Costas et al., 2010, at p. 1567; Leydesdorff et al., 2011). The Flemish ECOOM unit for evaluation in Leuven (SOOI), however, has developed a new classification system for journals (Glänzel & Schubert, 2003). Other authors have refined the journal lists within specific WCs to enable a more precise evaluation of a given discipline (e.g., Van Leeuwen and Calero-Medina, 2012). In the meantime, another journal classification system in terms of fields and subfields has been made available by Scopus.\(^5\)

The further development of computer power and software makes it possible nowadays to generate algorithmically a comprehensive map and classification of the aggregated journal-journal relations provided by the Journal Citation Reports (JCR) of the (Social) Science Citation Index. Using 2012 data and two of the new algorithms (Newman & Girvan, 2004; Rosvall & Bergstrom, 2008), Rafols & Leydesdorff (2009) compared the resulting classifications with the WCs and with Schubert & Glänzel’s (2003) revision as two content-based classifications. They found that the correspondences among the main categories are sometimes as low as 50% of the journals included; most of the mismatched journals appear to fall in areas in close proximity to the main categories. The results of the various decompositions are roughly consistent, but the overlap is imprecise. The algorithmic constructs are more specific than the content-based classification of the ISI and SOOI, but the algorithms produce much more skewed distributions.

\(^{5}\) The field/subfield classification of Scopus is available in the journal list from [http://www.elsevier.com/online-tools/scopus/content-overview](http://www.elsevier.com/online-tools/scopus/content-overview). WCs are available (under subscription) at [http://images.webofknowledge.com/WOKRS56B5/help/WOS/hp_subject_category_terms_tasca.html](http://images.webofknowledge.com/WOKRS56B5/help/WOS/hp_subject_category_terms_tasca.html).
in terms of the number of journals per category. Human indexers try to avoid this. However, the content-based sets are less clearly divided because the boundaries among them are blurred by the multiple assignments by indexers.

In addition to the skew in the distributions generated in the algorithmic solutions—with large tails of singletons—the randomness in the seed number used to begin each run makes the algorithmic classifications irreproducible from year to year (Lambiotte, personal communications, from 10 October 2008 to 16 December 2009). It is unclear whether the differences in outcomes between two runs is due to relevant changes in the data or the randomness factor in the algorithm. This problem seemed unsolvable for a long time. However, more recent developments in software development encourage us to make another attempt to construct a reproducible classification. Among these new developments are:

1. The algorithms for the decomposition of large networks have been further developed since Newman & Girvan (2004). The programs of Blondel et al. (2008) and Waltman, van Eck, and Noyons (2010) for VOSviewer are seamlessly integrated in the context of Pajek, a program for the analysis and visualization of networks available in the public domain. These programs also provide modularity measures ($Q$ and $VOS Quality$, respectively) as indicators of the decomposability of the data.

2. Pajek-files can function as a kind of currency for the transport of files among network programs such as Gephi, ORA, VOSviewer, UCInet, etc., each with their specific strengths. Moreover, in addition to its clustering and mapping algorithms, VOSviewer specifically allows for visualizing large networks, because the labels fade in and out with the level of
granularity and without cluttering or overlap. The integration between Pajek and VOSviewer enables us to combine the options for network analysis, specific layouts (e.g., Kamada & Kawai, 1989), and statistics in Pajek (or UCInet) with the visualizations in VOSviewer.

3. Furthermore, the three-rings algorithm implemented in Pajek provides fast access to clique analysis (Batagelj & Zaveršnik, 2007; de Nooy & Leydesdorff, 2015). Cliques of three (or more) journals are the natural candidates for system formation through mechanisms of transitivity and triadic closure (Bianconi et al., 2014; Freeman, 1992 and 1996; Simmel, 1902);

When triads are considered as building blocks of systems, the clustering is agglomerative. In this study, we focus first on divisive clustering and postpone the analysis using triads to a next follow-up. Divisive clustering operates on the system and sorts similar elements together in subsystems, which can also be called partitions. Whereas the agglomerative clustering of triads (“cliques”; Hanneman & Riddle, 2005; cf. Freeman, 1996) can be otherwise parameter free, at least two parameters need to be chosen in the case of divisive clustering: the clustering algorithm and a similarity criterion (e.g., the cosine values between each two patterns). The fast decomposition algorithms that we use in this study contain such parameters; both Pajek and VOSviewer allow for changing them. Since our purpose is not to search a parameter space for optimal configurations, but to develop a classification system which is unambiguous and reproducible, we limit the analysis to default values in Pajek and VOSviewer.

Pajek provides a common framework for two decomposition algorithms denoted in this context as “VOS Clustering” (Van Eck et al., 2010) and the “Louvain Method” (Blondel et al., 2008),
respectively. Both clustering routines begin with a random seed. In VOSviewer itself this random seed is always chosen from a sheet with random numbers. As we shall see, this stabilizes the resulting number of clusters. We pursue the network decomposition in greater detail for the cluster that contains *Journal of the Association for Information Science and Technology* (JASIST) and *Scientometrics*, an example chosen because we feel legitimated to validate results in this area. Using the Journal Citation Reports 2014 of the Science Citation Index and the Social Science Citation Index (*n* of journals = 11,149), we study options for developing an unambiguous classification of the journals into subject categories on the basis of aggregated journal-journal citation data.

2. Data

The two Journal Citation Reports (JCRs) contain 8,618 journals in the Science Citation Index and 3,143 in the Social Science Citation Index, respectively. However, the combined set covers 11,149 journals since 612 journals are included in both databases. We first generated the asymmetrical 1-mode matrix of these 11,149 journals cited (rows) versus citing (columns) from the database using dedicated routines. Of the 11,149 journals, 11,143 (> 99.9%) form a single largest component. The density of the network is 0.0217 or, in other words, 2.17% of the possible relations are realized, leading to 2,699,210 lines. However, the average degree is 484.207, indicating that the network can not only be considered as a single (largest) component, but this component is also well-connected internally. The clustering coefficient of the network (CC1 in Pajek) is 0.220. This provides a measure for the transitivity in the network.\(^6\)

\(^6\) The Watts-Strogatz clustering coefficient is 0.347.
Of the approximately 2.7 million lines only 112 are single citation relations. In most cases, the database producer (Thomson Reuters) aggregates the long tails of the citation distribution under the heading “All others.” In a second matrix, citation relations below five were therefore removed from the data as unreliable noise. The largest component of this network contains 11,087 vertices (99.4% of 11,149), but the number of lines (in the network) is now reduced to 1,206,856 and the density is 0.010. The average degree is reduced to 216.495. In other words, only 62 journals are disconnected. In summary, this network is far more concentrated than the original one despite our minimal assumptions during the cleaning process.

Table 1: Network characteristics of the various matrices.

|                              | JCR (a) | Largest component (b; Figure 1) | Links ≥ 5 (c; Figure 2) |
|------------------------------|---------|---------------------------------|-------------------------|
| **N of journals (nodes)**    | 11,149  | 11,143                          | 11,087                  |
| **Lines**                    | 2,699,210 (10,829 loops removed) | 2,113,105                  | 939,986                 |
| **Density**                  | 0.0217  | 0.0340                          | 0.0153                  |
| **Average degree**           | 484.207 | 379.270                         | 169.565                 |
| **Cluster coefficient**      | 0.220   | 0.314                           | 0.255                   |

Table 1 shows the network characteristics of the various matrices. Column b—the largest component of the full set—has the highest density and the largest clustering coefficient. Removing the lines with values smaller than five can be expected to increase the number of unconnected clusters.

### 3. Decomposition

#### 3.1. Which algorithm to use?
Two routines are available for the decomposition: the so-called Louvain algorithm (Blondel et al., 2008) and the VOS algorithm. Using 2012 data and a similar design, Leydesdorff & Rafols (2014) found that the Louvain algorithm generated a lower number of singletons than the VOS algorithm, and therefore pursued the analysis with the Louvain algorithm. Table 2 shows the results of two runs using each routine in Pajek as a common framework. The numbers of clusters are different between runs, but the quality measures are similar. The quality of the decomposition is measured by the modularity $Q$ when using Blondel et al. (2008) and the parameter VOS Quality in the other case.

Table 2: Decomposition of the citation matrix for 11,149 journals using the Louvain or VOS algorithms in Pajek.

| Full matrix       | $N$ of clusters | $Q$ or VOS Quality |
|-------------------|-----------------|--------------------|
| Blondel et al. (2008) | 18              | 0.582              |
|                   | 19              | 0.582              |
| VOS (Pajek)       | 16              | 0.920              |
|                   | 20              | 0.921              |

Although the decompositions are somewhat different, 10 to 12 clusters are found in all runs using both algorithms after the tails of single journals are removed from the distributions. These classifications can be compared in terms of chi-square statistics, both in terms of their mutual consistency and in terms of their internal consistency among runs of the same algorithm. Cramer’s $V$ provides a summary statistics of the chi-square, which is convenient because it provides a measure for the association between zero and one. Additionally, we use chi-square statistics to test for statistical significance.
As to be expected, Cramer’s $V$ between the two classifications varies a bit, but $V \approx 0.812$ ($p < 0.001$). The internal consistency of the solutions in each of the two routines can be measured by using, for example, five drawings. In the case of the Blondel-algorithm Cramer’s $V = 0.912$ ($\pm 0.025$) and in the other case $V = 0.897$ ($\pm 0.027$). The results confirm Leydesdorff & Rafols’ (2014) preference for the Louvain algorithm; but there remain non-trivial differences in the resulting cluster structures using either program. The uncertainty thus introduced, is unfortunate from the perspective of the envisaged mapping in layers, since uncertainty will be multiplied at each level of the decomposition. Note that in the case of four layers, for example: $0.9^4$ is only 0.66.

### 3.2. Decomposition with reduced data

As noted above, we constructed a second matrix in which values of aggregated citation lower than five were considered as noise and therefore removed. Using this matrix, Table 3 provides the analogue of Table 2. The numbers of clusters in the largest component are added between brackets. In this case the Blondel-algorithm generates a tail of 67, and the VOS algorithm more than 80 singletons.

**Table 3:** Decomposition of the reduced citation matrix for 11,149 journals using the Louvain or VOS algorithm in Pajek.

| Matrix with values $\geq 5$ | $\text{N of clusters}$ | $Q$ or VOS Quality |
|----------------------------|-------------------------|---------------------|
| Blondel et al. (2008)      | 80 (13)                 | 0.608               |
|                            | 80 (13)                 | 0.602               |
| VOS (Pajek)                | 103 (19)                | 0.952               |
|                            | 106 (17)                | 0.952               |
The two algorithms thus behave rather differently using the reduced data. Cramer’s \( V \), however, is higher both when comparing the results of the two algorithms (\( 0.92 < V < 0.93 \)) and in the case of comparing two solutions using the same algorithm (\( V > 0.96 \)). The 60+ isolates probably contribute to the improvement on this criterion.

Although there are arguments for discarding the tails of the distribution, by doing so one inadvertently introduces a parameter: the relative weights of the tails can be expected to vary among fields of science. In our opinion, one must therefore have strong arguments for introducing this additional parameter; the decomposition (see Table 1) did not provide such arguments. On the contrary, the largest component of the full matrix had the highest values for both the density and the clustering coefficients. Do the resulting maps perhaps provide an argument for choosing one of the two algorithms?

4. Maps

Using VOSviewer, the maps (see Figures 1 and 2) are based on the largest components of the full matrix and the matrix with reduced data, respectively. In these two cases, VOSviewer distinguishes among 11 and 39 clusters, respectively.
Figure 1: Eleven clusters of 11,143 journals (largest component of the JCR matrix); VOSviewer used for classification and visualization. This map can be web-started at
http://www.vosviewer.com/vosviewer.php?map=http://www.leydesdorff.net/journals14/jcr14.txt&cluster_colors=http://www.leydesdorff.net/journals14/colors14.txt&label_size_variation=0.3&zoom_level=1&scale=0.9
Figure 2: Thirty-nine clusters of 11,087 journals in the case of reduced data (links of fewer than five were deleted). This map can be web-started at
http://www.vosviewer.com/vosviewer.php?map=http://www.leydesdorff.net/journals14/jcr14lt5.txt&cluster_colors=http://www.leydesdorff.net/journals14/colors14.txt&label_size_variation=0.3&zoom_level=1&scale=0.9
For example, a group of 53 astrophysics and astronomy journals is distinguished in Figure 2 (at the bottom right), but integrated in the physics group in Figure 1. In both cases, between 50 and 60 journals are set apart as ophthalmology, but in the latter case an additional group of more than 400 journals is distinguished at the interface between chemistry (notably, analytical chemistry) and pharma. Otherwise the differences are mainly in the isolates (see Figure 3). Comparison of Figures 1 and 2—which are similarly scaled—shows, in our opinion, that Figure 1 is richer: the lobes (e.g., astrophysics journals at the bottom right) are more outreaching. The links below five thus contribute to the quality of the map. Setting a threshold has an adverse effect: without the minor links, which are specific, the larger journals show as more densely packed.

Choosing this full-matrix representation, we will work with nine top-layer fields of science because two of the eleven clusters are singletons (Prog Tumor Res and Epidemics Neth; see Table 4 and Figure 3). As noted, the designation is not provided by the algorithms, but based on our reading.
Figure 3: Nine fields of science.

Table 4: Nine fields of science distinguished in JCR at the top level

| Field            | N   |
|------------------|-----|
| Social Sciences  | 3,131|
| Medicine         | 1,943|
| Computer Science | 1,939|
| Environmental    | 1,911|
| Chemistry        | 684 |
| Bio-Medical      | 672 |
| Physics          | 462 |
| Neuro Sciences   | 343 |
| Ophthalmology    | 56  |

Note that the designations are provided by us as analysts. The group of social-science journals is by far the largest. The journals in the social sciences obviously share a citation pattern that is
different from the other groups. Ophtalmology includes a relatively small set of journals. In Figure 1, this cluster is difficult to track without first zooming in on the brown-colored journals at the interface between the bio-medical journals (light blue) and medical journals (green) in the upper left quadrant.

As noted above, we pursue the analysis using *JASIST* and *Scientometrics* as our leads for the decomposition. The decomposition of the other branches is equally possible, as we will demonstrate using other, more qualitatively oriented journals in science and technology studies as an example (Leydesdorff & Van den Besselaar, 1997; Wyatt *et al.*, 2016). Table 5 provides a summary of the decompositions that will be pursued. We envisage completing the classification in a next project (Zhou & Leydesdorff, in preparation).
### Table 5: Decomposition of the JCR at different levels (fields, subfields, specialties)

| Fields | Subfields/Disciplines | Specialties | N of journals |
|--------|-----------------------|-------------|---------------|
| 1. Social Sciences |  |  | 3,131 |
| 2. Medicine |  |  | 1,943 |
| 3. Computer Science |  |  | 1,939 |
| 4. Environmental Sciences |  |  | 1,911 |
| 5. Chemistry |  |  | 684 |
| 6. Bio-Medical Sciences |  |  | 672 |
| 7. Physics |  |  | 462 |
| 8. Neuro Sciences |  |  | 343 |
| 9. Ophthalmology |  |  | 56 |

Decomposition of 1. Social Sciences

| Subfields/Disciplines | Specialties | N of journals |
|-----------------------|-------------|---------------|
| 1.1. Discipline-oriented social sciences |  | 1,008 |
| 1.2. Application-oriented social sciences |  | 385 |
| 1.3. Health |  | 345 |
| 1.4. Economics |  | 335 |
| 1.5. Mental Health |  | 267 |
| 1.6. Administration |  | 255 |
| 1.7. Language |  | 188 |
| 1.8. Psychology |  | 146 |
| 1.9. Law |  | 117 |
| 1.10. Library & Information Science |  | 52 |
| 1.11. Transport |  | 33 |

Decomposition of 1.1. Discipline-oriented social sciences

| Subfields/Disciplines | Specialties | N of journals |
|-----------------------|-------------|---------------|
| 1.1.1. Anthropology |  | 258 |
| 1.1.2. Sociology |  | 143 |
| 1.1.3. History and Philosophy of Science |  | 128 |
| 1.1.4. Geography |  | 101 |
| 1.1.5. International Relations |  | 100 |
| 1.1.6. Political Science |  | 78 |
| 1.1.7. Environmental |  | 69 |
| 1.1.8. Law |  | 63 |
| 1.1.9. Communication Studies |  | 43 |
| 1.1.10. Archaeology |  | 25 |

(...)

Decomposition of 1.1.3. History and Philosophy of Science

| Subfields/Disciplines | Specialties | N of journals |
|-----------------------|-------------|---------------|
| 1.1.3.1. Science Studies (STS) |  | 10 |
| 1.1.3.2. Science Education |  | 35 |
| 1.1.3.3. History of Science |  | 26 |
| 1.1.3.4. Health Ethics |  | 2 |
| 1.1.3.5. Socio-biology |  | 18 |
| 1.1.3.6. Philosophy of Science |  | 17 |
| 1.1.3.7. Ethics and Social Philosophy |  | 28 |

(...)

Decomposition of 1.10. Library & Information Science

| Subfields/Disciplines | Specialties | N of journals |
|-----------------------|-------------|---------------|
| 1.10.1. Library Science |  | 9 |
| 1.10.2. Information & Organization |  | 3 |
| 1.10.3. Publishing |  | 3 |
| 1.10.4. ASLIB journals |  | 3 |
| 1.10.5. Scientometrics |  | 1 |
| 1.10.6. JACS + Z Bibl Bibl |  | 1 |
| 1.10.7. Can J Inform Lib Sci |  | 1 |
4.1.  Further decomposition of the set of 3,131 social-science journals

We pursued the decomposition using the choices specified above. Figure 4 shows a map of the eleven clusters that are summarized in Table 6. The first and largest set is composed of theoretically oriented journals in the social sciences \( N = 1,008 \) with a citation pattern different from some disciplinary clusters (e.g., economics and psychology) and some fields of application (e.g., “health” and “transport”). “Library & information science” is distinguished at this level as a group of 52 journals which we will further analyze in the next section.

Table 6: Decomposition of the set of 3,131 journals in the social sciences

| Subfields                        | N    |
|----------------------------------|------|
| Discipline-oriented social science | 1,008|
| Application-oriented social science | 385  |
| Health                           | 345  |
| Economics                        | 335  |
| Mental Health                    | 267  |
| Administration                   | 255  |
| Language                         | 188  |
| Psychology                       | 146  |
| Law                              | 117  |
| Library & Information Science    | 52   |
| Transport                        | 33   |
| Sum                              | 3,131|

Table 6 shows that clusters can sometimes be designated as disciplines (e.g., economics, psychology, law), but in other cases as fields of application (e.g., transport, health). As noted, the designation is not a result of the analysis, but based on the semantics which we as analysts use for understanding the algorithmic results; in other contexts, one may wish to use other terminology.
Figure 4: Eleven clusters of citation patterns among 3,131 journals in the social sciences. This figure can be web-started at http://www.vosviewer.com/vosviewer.php?map=http://www.leydesdorff.net/journals14/level2/sosci.txt&label_size_variation=0.4&scale=0.9
4.2. Decomposition and map of 52 journals in library and information science

The 52 journals in library and information science contain a largest cluster of 28 journals which can be denoted as “library science” *sensu stricto*. Among the other 24 journals, three are identified as a separate group which we denote as “scientometrics.” These are *Scientometrics, Journal of Informetrics*, and *Research Evaluation*. *JASIST*—represented both as the *Journal of the American Society for Information Science and Technology* (that is the name until 2014) and the *Journal of the Association for Information Science and Technology* (that was the name since 2014)—forms a separate group with *Z Bibl Bibl*. The *Malays J Lib Inf Sci* is placed in a cluster with the two ASLIB journals in the database: *ASLIB J Inform Manag* and *ASLIB Proc*. The *Can J Inform Lib Sci* is a singleton.

In Appendix 1, these 52 journals are compared with the 85 journals subsumed under the category “information science & library science” in WoS.\(^7\) *Issues Sci Technol* and *J Legal Educ* are not counted as LIS in WoS, but belong to the specialty in terms of their cited/citing patterns in our classification. However, 33 journals in the WoS category are not counted as LIS using our map and classification. These journals are mainly about the management of information systems, such as *MIS Quarterly*. Subsuming these two groups of journals into a single WC on the basis of the word “information” has been a major problem in the WoS classification (Leydesdorff & Bornmann, 2016). The two groups are very different in terms of citation behavior. This entire group is classified differently in this decomposition: under the category 1.6 in Table 5, which is labeled “Administration” and contains 255 journals in total.

\(^7\) In WoS, this category is abbreviated as “NU”. 
Figure 5: Map of 52 journals classified as Library and Information Science. This file can be web-started at http://www.vosviewer.com/vosviewer.php?map=http://www.leydesdorff.net/journals14/level3/lis52map.txt&network=http://www.leydesdorff.net/journals14/level3/lis52net.txt&zoom_level=1.5&label_size_variation=0.3&scale=1.1&colored_lines&curved_lines&n_lines=10000
4.3. *The disciplinary-organized group of the social sciences (cluster 1.1)*

The largest group at the second level was labeled by us as “discipline-oriented social sciences” ($N = 1,008$). Note that the disciplines of economics (335 journals) and psychology (146 journals) are already separated out at this level, as was the group of 52 LIS journals discussed above. The next decomposition of this largest component provides a structure of seven disciplines in the social sciences and three in the humanities. These distinctions are in our opinion very meaningful. Figure 6 provides the map and Table 7 the categories and numbers of journals involved.
Figure 6: Ten clusters among 1,008 journals in disciplinarily organized social and cultural sciences. This file can be web-started at http://www.vosviewer.com/vosviewer.php?map=http://www.leydesdorff.net/journals14/level3/sosci1_map.txt&label_size_variation=0.4&scale=0.9&colored_lines&n_lines=10000&normalized_lines&curved_lines
Table 7: Decomposition of the discipline-oriented group of 1,008 journals in the social sciences

| Disciplines                                 | N   |
|---------------------------------------------|-----|
| Anthropology                               | 258 |
| Sociology                                  | 143 |
| History and Philosophy of Science           | 128 |
| Geography                                  | 101 |
| International Relations                     | 100 |
| Political Science                          | 78  |
| Environmental                              | 69  |
| Law                                        | 63  |
| Communication Studies                      | 43  |
| Archaeology                                | 25  |
| **Total**                                   | 1,008 |

The three groups of journals in the humanities make the map excentric. Most pronouncedly the archaeology group (N = 25) at the top right is hardly connected to other groups except anthropology. At the bottom right, one observes a large group of journals involved in the study of science and technology from different perspectives (history, philosophy, education, etc.). The law journals (N = 63) shape a lobe at the bottom of the figure. We pursue the decomposition of the history and philosophy of science (HOPOS) group in order to show the position and fine-structure of science and technology studies (STS).
4.4. History and Philosophy of Science (HoPoS) and Science Studies (STS) (decomposition of cluster 1.1.3 at level 4)

**Figure 7:** Eight clusters of 128 journals in *history and philosophy of science (HoPoS)*. Layout according to Kamada & Kawai (1989), clustering according to Blondel *et al.* (2008), using Pajek. The map can be web-started at [http://www.vosviewer.com/vosviewer.php?map=http://www.leydesdorff.net/journals14/level4/sts_map.txt&network=http://www.leydesdorff.net/journals14/level4/sts_net.txt&label_size_variation=0.4&scale=0.9&cluster_colors=http://www.leydesdorff.net/journals14/level4/sts_col.txt&colored_lines=&n_lines=10000&curved_lines](http://www.vosviewer.com/vosviewer.php?map=http://www.leydesdorff.net/journals14/level4/sts_map.txt&network=http://www.leydesdorff.net/journals14/level4/sts_net.txt&label_size_variation=0.4&scale=0.9&cluster_colors=http://www.leydesdorff.net/journals14/level4/sts_col.txt&colored_lines=&n_lines=10000&curved_lines)
Table 8: Decomposition of the group of 128 journals in history and philosophy of science (HoPoS)

| Specialty                          | N  | WC |
|------------------------------------|----|----|
| Science Studies (STS)              | 20 | 9  |
| Science Education                  | 10 | 1  |
| History of Science                 | 35 | 34 |
| Health Ethics                      | 26 | 1  |
| Socio-Biology                      | 2  | 0  |
| Philosophy of Science              | 18 | 11 |
| Ethics and Social Philosophy        | 17 | 1  |
|                                    | 128| 57 |

In the case of Figure 7, we used another algorithm for the layout in Pajek (Kamada & Kawai, 1989) because the mapping of VOSviewer was less informative. This group of 128 journals can be compared with the category “History & Philosophy of Science” in WoS containing 67 journals, of which 57 are included among these 128. The additional column in Table 8 teaches us that the health ethics and the science education journals in particular are located differently according to the WoS classification.

4.5. Science Studies (STS) (level 5; 20 journals)

Let us pursue the analysis in this case also at the next-lower level of the 20 journals labeled above as STS. The distinctions are now fine-grained and precise. The group on the right is focused on ethical discussions about science-and-society issues in engineering and engineering education. Radical STS is concentrated in a group of five journals around Social Studies of Science (green). Science & Public Policy, Minerva, and Public Understanding of Science form the core of a third group (blue) that is further extended with two minor journals. Discussions at the philosophical level are indicated as two journals (Soc Epistemol and Sci Technol Soc) represented by pink-colored nodes.
Figure 8: Twenty journals in the specialty of STS/sociology of science; four clusters distinguished. This figure can be web-started at http://www.vosviewer.com/vosviewer.php?map=http://www.leydesdorff.net/journals14/level5/sss_map.txt&network=http://www.leydesdorff.net/journals14/level5/sss_net.txt&label_size_variation=0.4&scale=1.1&colored_lines&n_lines=10000&curved_lines
5. Conclusions and discussion

Using VOSviewer and Pajek, it is possible to make a full classification system of journals on the basis of the aggregated journal-journal citation data provided in the two JCRs. We elaborated this system in one branch given our interest in LIS and STS; but there are no reasons why this could not be done for the other eight branches which were first distinguished as main fields. At the second level, the designation in terms of subfields and disciplines is a bit more complex: “economics” and “psychology,” for example, are distinguished at the same (second) level as fields of application like “health” and “transport.” Other disciplines (e.g., “sociology” or “anthropology”) are distinguished only at the third level. In summary, the database contains a set of organized densities of citations. Words such as subfields and disciplines can be considered as part of the semantics that we as analysts bring to the data.

The resulting clustering is unambiguous and reproducible. Therefore, it can also be used for comparison among years. Apart from the parameters built into VOSviewer, all data is exploited and no further decisions implying parameters are made. We thus made an attempt to solve the problem formulated by Rafols & Leydesdorff (2009) that none of the content-based or algorithmically generated classifications were both sufficiently precise and reproducible. The content-based ones suffer from indexer effects and the algorithmically generated ones were vulnerable to random factors in the initial seed. When maps and classifications are uncertain, reliable normalizations are impossible; particularly in the case of interdisciplinary science.

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8 A JCR of the Arts & Humanities Citation Index is not available; see Leydesdorff, Hammarfeldt & Salah (2011) for a mapping of this index.
The proposed solution is based on commonalities in citation behavior, but remains a hierarchical and divisive clustering tree. The attribution of a journal to a place in the structure is unambiguous, but journals themselves are not homogenous units of analysis (Klavans & Boyack, 2015). The clustering is based on the main trends in the citation distribution after aggregation of the distributions at the level of articles. However, an individual article may differ substantially in its citation behavior or being-cited characteristics from the main trend in the journal in which it is published.

Articles are aggregated into journals and journals into journal categories. The resulting citation distributions are heavily skewed, showing that the communication is very specific, since authors carefully select their references. The resulting journal system can be considered as an eco-system evolving with variations at the bottom leading occasionally to speciation, extinction, etc. The structures (journals and journal groups) provide selection environments that are evolving under pressure from gradual changes in the prevailing variation. Much variation can be discarded by the system as noise, but incidentally the system is always changing.

One substantive conclusion of this study is that we did not find the effect of PLoS ONE disturbing the classification which we expected on the basis of the results reported by de Nooy & Leydesdorff (2015). The growth of PLoS ONE seems to have changed the dynamics of the system, but not (yet?) its cognitive organization. Secondly, the social sciences formed the largest group in the first round: more than 3,000 of the 11,000+ journals exhibit a specific citation pattern different from the other sciences. At a next round, more than 1,000 of these 3,000+ journals form the core journals of the various disciplines in the social sciences; the others are
application oriented. One of the theory-oriented groups was further analyzed with a focus on science and technology studies. Note how differently journals like *Scientometrics* or *Social Studies of Science* are positioned in this classification system despite their common background in science studies (Leydesdorff & Van den Besselaar, 1997; Wyatt *et al*., 2016). This classification is not in terms of cognitive content, but in terms of common patterns in citation behavior; it can therefore serve excellently for the purpose of normalization in bibliometric evaluations. The substantive interpretation of the clusters is not directly relevant.

However, this caveat has another normative implication: one would like to use (change in) the journal map as a baseline for the evaluation of policy initiatives (Leydesdorff, 1986; Studer & Chubin, 1980, pp. 269 ff.). Policy initiatives, however, are based on considerations other than citation behavior. We would therefore expect these maps to be of limited value for this purpose. The overall map (Figure 1), however, provides an excellent platform for portfolio analysis (Leydesdorff, Heimeriks, & Rotolo, 2016). Using the distances on the map, one can also elaborate the ecological disparity and thus compute, for example, Rao-Stirling diversity (Rafols & Meyer, 2010; Stirling, 2007; Zhang *et al*., in press).

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Appendix 1: Comparison of the LIS category (52 journals) with the WC “information science & library science” (85 journals).

| VOSviewer                              | WoS                        |
|----------------------------------------|----------------------------|
| Afr J Libr Arch Info                   | Afr J Libr Arch Info       |
| Aslib J Inform Manag                   | Aslib J Inform Manag       |
| Aslib Proc                             | Aslib Proc                 |
| Aust Acad Res Libr                    | Aust Acad Res Libr         |
| Aust Libr J                            | Aust Libr J                |
| Can J Inform Lib Sci                  | Can J Inform Lib Sci       |
| Coll Res Libr                          | Coll Res Libr              |
| Data Base Adv Inf Sy                   | Data Base Adv Inf Sy       |
| Econtent                               | Econtent                   |
| Electron Libr                          | Electron Libr              |
| Ethics Inf Technol                     | Ethics Inf Technol         |
| Eur J Inform Syst                      | Eur J Inform Syst          |
| Gov Inform Q                           | Gov Inform Q               |
| Health Info Libr J                    | Health Info Libr J         |
| Inf Tarsad                             | Inf Tarsad                 |
| Inform Cult                            | Inform Cult                |
| Inform Dev                             | Inform Dev                 |
| Inform Manage-Amster                   | Inform Manage-Amster       |
| Inform Organ-Uk                        | Inform Organ-Uk            |
| Inform Process Manag                   | Inform Process Manag       |
| Inform Res                             | Inform Res                 |
| Inform Soc                             | Inform Soc                 |
| Inform Soc-Estud                       | Inform Soc-Estud           |
| Inform Syst J                          | Inform Syst J              |
| Inform Syst Res                        | Inform Syst Res            |
| Inform Technol Libr                    | Inform Technol Libr        |
| Inform Technol Peopl                   | Inform Technol Peopl       |
| Int J Comp-Supp Coll                   | Int J Comp-Supp Coll       |
| Int J Geogr Inf Sci                    | Int J Geogr Inf Sci        |
| Int J Inform Manage                    | Int J Inform Manage        |
| Investig Bibliotecol                   | Investig Bibliotecol       |
| Issues Sci Technol                     | Issues Sci Technol         |
| J Acad Libr                            | J Acad Libr                |
| J Am Med Inform Assn                   | J Am Med Inform Assn       |
| J Am Soc Inf Sci Tec                   | J Am Soc Inf Sci Tec       |
| J Assoc Inf Sci Tech                   | J Assoc Inf Sci Tech       |
| J Assoc Inf Syst                       | J Assoc Inf Syst           |
| J Comput-Mediat Comm                   | J Comput-Mediat Comm       |
| J Doc                                  | J Doc                      |
| J Glob Inf Manag                       | J Glob Inf Manag           |
| Journal Name | Full Journal Name |
|--------------|------------------|
| J Glob Inf Tech Man | J Health Commun |
| J Inf Sci | J Inf Sci |
| J Inf Technol | J Inf Technol |
| J Informer | J Informer |
| J Legal Educ | J Knowl Manag |
| J Libr Inf Sci | J Libr Inf Sci |
| J Manage Inform Syst | J Manage Inform Syst |
| J Med Libr Assoc | J Med Libr Assoc |
| J Organ End User Com | J Organ End User Com |
| J Scholarly Publ | J Scholarly Publ |
| J Strategic Inf Syst | J Strategic Inf Syst |
| Knowl Man Res Pract | Knowl Man Res Pract |
| Knowl Organ | Knowl Organ |
| Law Libr J | Law Libr J |
| Learn Publ | Learn Publ |
| Libr Collect Acquis | Libr Collect Acquis |
| Libr Hi Tech | Libr Hi Tech |
| Libr Inform Sc | Libr Inform Sc |
| Libr Inform Sci Res | Libr Inform Sci Res |
| Libr J | Libr J |
| Libr Quart | Libr Quart |
| Libr Resour Tech Ser | Libr Resour Tech Ser |
| Libr Trends | Libr Trends |
| Libri | Libri |
| Malays J Libr Inf Sc | Malays J Libr Inf Sc |
| Mis Q Exec | Mis Q Exec |
| Mis Quart | Mis Quart |
| Online Inform Rev | Online Inform Rev |
| Portal-Libr Acad | Portal-Libr Acad |
| Prof Inform | Prof Inform |
| Program-Electron Lib | Program-Electron Lib |
| Ref User Serv Q | Ref User Serv Q |
| Res Evaluat | Res Evaluat |
| Restaurator | Restaurator |
| Rev Esp Doc Cient | Rev Esp Doc Cient |
| Scientist | Scientist |
| Scientometrics | Scientometrics |
| Serials Rev | Serials Rev |
| Soc Sci Comput Rev | Soc Sci Comput Rev |
| Soc Sci Inform | Soc Sci Inform |
| Telemat Inform | Telemat Inform |
| Transinformação | Transinformação |
|-----------------|-----------------|
| Z Bibl Bibl     | Z Bibl Bibl     |