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A measure of similarity between scientific journals and of diversity of a list of publications

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Abstract : The aim of this note is to propose a definition of the scientific diversity and corollarily, a measure of the “interdisciplinarity” of collaborations. With respect to previous studies, the proposed approach consists of 2 steps : first, the definition of similarity between journals and second, these similarities are used to characterize the homogeneity (or, on the contrary the diversity) of a publication list (that can be for one individual or a team).

1 Introduction

Interdisciplinarity is, nowadays, of interest for several reasons and by lots of people and institutions. Let us just quote two recent initiatives in France : the creation of the "mission interdisciplinaire" at CNRS (<http://www.cnrs.fr/mi/>) or the report of the AERES that proposes interesting direction for evaluation of interdisciplinary [1] based on qualitative analysis. We do not intend to discuss the reasons of such interest and refer to [2] for a detailed and recent review about interdisciplinarity.

In this note, we propose a method for quantifying the interdisciplinarity only based on bibliometric data, without any a priori classification of scientific domains and/or arbitrary knowledge on their proximity. The obtained results should be compared with existing classification and analysed by scientists to validate (or not !) their meaningful interest.

The actual note is a very preliminary description of the idea and it has not been tested on bibliometric data. The author is not an expert in scientometrics and do not have acces to large database that are necessary to test the approach. Lot of studies have been done about co-authorship (see e.g. [3] and the reference cited therein, at bottom of page 159). However, the actual approach (with two steps as detailed after) has not yet been proposed up to my knowledge. In the actual version, this note is not aimed for publication and suggestions are warmly welcome in particular to be informed about

previous works in the same spirit.

The goal is to define a measure of the interdisciplinarity within a publication list (for one individual, team, laboratory, institution). Such quantitative information has to be complemented by a finer analysis for scientists to determine the corresponding relevance of the scientific collaborations. We just try to propose an approach to see its feasibility and, hopefully, to prove its capability to characterize interdisciplinary studies.

The proposed approach is based in two steps : first, we define, from a bibliographical database, a measure of the similarity between scientific journals based on co-authorship i.e. the more 2 journals have co-authors, the closer they are (this will be made more precise later). It can be objected that we do not measure scientific “proximity” but actual practices of publications. The second step consists in using these similarities to characterize whether or not a publication list is an scientifically “homogeneous” set.

It is believed that information on co-authorship is more reliable to evaluate pluridisciplinary collaborations than using citations. Indeed, it is rather common that a paper e.g. in mathematics cites several articles in an application domain, to illustrate the origin of the scientific problem or to justify the modelling choice done but the core of the paper can be entirely focused on mathematical analysis. On the other hand, signing a paper with colleague mean (we hope so) a mutual interest and work within the paper.

Note also that publishing a paper in a so called pluridisciplinary journal (what is the definition of such journals ?) does not mean that the article is itself the result of a collaboration between several scientific domain.

It can be argued that the proposed approach measures more the originality of a set of publication, that is the reason why it is called scientific diversity, since the similarity counts for the existing collaborations, even if they are already interdisciplinary.

Several web site indeed provide informations on scientific collaborations such as *researgate*, *resaerchid*, *googlescholar*, *sciencewatch* (non exhaustive list) and can be interested in providing new services and informations to their visitors (see in the reminder for examples).

The proposed analysis can also be of interest for editors of scientific journal (they may already have similar tools but they are not known by the author). The method is presented in a algorithmical way in order to facilitate its implementation. Let repeat that experiment feedbacks are welcome.

2 Data , notations

The method relies on bibliographical data (the use of the largest possible database will provide the more relevant informations).

Let us precise the notations.

The database consists in a list of articles, that will be denoted by an unique identifier (that can be consider as in integer) using the letter i . Each article i (where $i \in 1 \dots N$) will be described by

- the journal of publication, denoted by an unique identifier, j . More precisely, $j(i)$ is the journal where article i has been published. The list of journal is finite (even if its length increases with the creation of new journals each year). To fix the idea about 13000 journals are included in the Thomson-ISI database.
- $y(i)$ is the year of publication of the article i .
- $K(i)$ is the list of (co-)authors of the article i . The authors have to be identified i.e. each individual should have an unique identifier, that can be represent by an integer. We will use k for authors. Thus, $k \in K(i)$ means that the author k is (one of) the author of article i ¹
- $p(i)$ is the number of pages of the article. This is useful to differentiate short note and more detailed study although this can be discussed. The interest of a paper is, of course, not proportional to its length but it can be consider as an useful indicator, once renormalized for a given journal (or a given author).

In this note, we will use capital letters to represent lists. J is the (finite) list of all the journals. I is the list of all the articles. For example, we shall note $I(j)$ the list of articles published by the journal j or $I(j, k)$ the list of articles published by author k in the journal j or $I(j, k, y)$ the list of articles published by author k in the journal j within the year y . Similarly $J(k, y)$ represents the list of journals where author k published in the year y .

We note with N the cardinal of a set. E.g. $N(I(k))$ is the total number of articles by author k . P is the total number of pages, e.g. $P(j, y) = \sum_{i' \in I(j, y)} p(i')$ is the total number of pages in the journal j during year y .

According to usual consideration in the mathematical science field (which is the domain of the author), the weigth of a given article will be shared uniformly between all the authors of the article. This point is naturally questionnable but claiming that the importance of a paper is proportional to its number of authors as, e.g. in the computation of citations or impact factor can also be under discussion. Let us refer to [4] for a discussion on the question of multiple authorship.

¹ This is the reason why I can not test the proposed approach on the data of HAL french publication deposit.

3 Journal similarity

Using these notations, we shall now define the similarity between journals by considering, for all articles and of (co-)authors of this article, all other articles by the same author.

More precisely, for all $i \in I$ and all $k \in K(i)$ and all $i' \in I(k)$, the similarity between journal $j(i)$ and $j(i')$ increases as follows

$$S(j(i), j(i'))_+ = \min\left(\frac{p(i)}{N(K(i))}, \frac{p(i')}{N(K(i'))}\right), \quad (1)$$

note that $S(j(i), j(i'))$ will be increased by the same value (when exchanging the role of i and i'). We propose to increment the similarity between the 2 journals by the min value of the “weight” of the 2 articles (number of pages divided by the number of authors) instead of using the arithmetic mean e.g. because it is believed that the scientific proximity is stronger if the 2 papers have the same weights (with the same arithmetic weight). Other choices, like for example, a geometric mean (\sqrt{ab}) may give better results. The only way to choose the right formulae will be to test several choices and compare the obtained similarity matrix (see below some ideas to help in the choice or in the validation of the relevant definition of similarity).

One can discuss about the normalization of the page number i.e. to divide the number of pages with respect with the total number of pages within the journal j . In other words, we propose to replace $p(i)$ in the above equation by

$$\tilde{p}(i) = p(i)/P(j(i)).$$

These variants should be tested as soon as data are available. It is obvious that the non-normalized choice will increase the impact of journals which produces a lot of paper and/or pages whereas the similarity should measure a proximity between journal that should not be correlated to the “size” of the journal. Therefore, the normalization using normalized by the total number of paper should be more pertinent.

Remarks

- By construction, $S(j, j) > 1$ since $i \in I(k), \forall k \in K(i)$ (or $S(j, j) > P(j)$ if we do not use the normalized version). The effective value will measure if the same authors are lot of their publications in the journal j .

- Similarity can be computed for a given year (or period) by taking into account only the article of the corresponding year (or period).

- It is clear that the matrix S will be coarse and it will be necessary to take into account the second order co-authorship (i.e. the co-author of co-authors, following the

idea of the Erdos number ref?). Let us define by summing the binary interactions as follows

$$S_2(j, j') = \sum_{j''} S(j, j'')S(j'', j')$$

By construction we see that $S_2 = S^2$. Then we can use $\tilde{S} = S + \theta S_2$ where θ is a constant than represents the relative weighth of secondary co-authorship. Once again, this should be tested on a real / huge database (see below).

Validation phase

At this stage, it will be necessary to test if the proposed similarity fits with usually used classification by scientific domain. More precisely, it will be interesting, using a given disciplinary classification, to verify wheater or not the averaged similarity inside a scientific domain is smaller (or not and to what extend) than the same average over all journals. It can serve also to compute the average similarity between two choosen different domains by computing the average value of $S(j, j')$ for any j in domain 1 and j' in domain 2. This will provide a similarity matrix between scientific domains and it has to be analysed if it corresponds to usual classifications of scientific domains.

Note that, when considering article from "multidisciplinary" journals (using an arbitrary list/classification), its citations are affected to a domain, according to the citation in the article (see <http://sciencewatch.com/about/met/classpapmultijour/>).

Other study like clustering can be developped using this similarity between journals [5, 6].

It can also be checked if the "generalist" journals have a larger (average) similarity than the more specific one. One can e.g. use the 22 so-called broad fields (see <http://www.in-cites.com/journal-list/>) in the "Essential Science Indicators database" of Thomson-ISI .

Possible Services - Utilities

Once validated, this similarity between journals can be of interest for editors to evaluate the impact of their editorial choice on the scientific positioning. For example, if an effort is done in order to encourage paper in a near domain (that corresponds to a given subset of journals), it can be observed that the average similarity of the journal with the one of the given subset increases with time (by computing the averaged similarity restricted to successive years). It can also help editors to see if a journal evolves for a larger specialization or on the contrary is more and more multidisciplinary.

4 Interdisciplinarity or scientific diversity index

Let us now consider that the matrix of similarity S is known (and validated).

In this section, we will construct an index for any arbitrary list L of publications (that can be the one of a person, a team, a laboratory, an institution, a journal, an editor).

Let us define the, so called scientific diversity index SD of the list L as the averaged similarity between journal in the list weighted with the respective weights of the article. In other words,

$$SD(L) = \frac{1}{N(L)^2} \sum_{i \in L} \sum_{i' \in L} S(j(i), j(i')) p(i) / N(K(i)). \quad (2)$$

Note that the index is not related to the quantity of paper (if one duplicates the list, the number of elements in the double sum is multiplied by 4 but $N(L)$ is multiplied by 2 and the value is unchanged).

The SD index has not to be considered as an indicator of the quality of the articles in list L , but on the contrary this is a qualitative indicator on this list of articles. Note that this index is constructed using statistical / averaged bibliographical quantities. It is therefore very questionable to use it on a small list of articles and thus, it is likely more suitable to characterize collective list of publications than the one of individuals except for scientists with a sufficiently long publication list in order the result to be significant (for such scientists, it will be interesting to see if their SD is correlated with the number of articles (I index i.e. $N(I(k))$ with our notation) or citations (h index for example).

There are a lot of studies that can be done using this index, which, again, does not measure the "quality" or the "importance" or "impact" (in terms of influence on other scientists) but only the relative diversity or variety or originality of a list of publications with respect to others.

Such an indicator will only have to be used with a lot of care and only relative comparisons make sense (the exact value has no interest). For example, one can think to compute, for the list of a given author (denoted by $I(k)$ with our notations), one can compare the value of $SD(I(k))$ with the corresponding value for all co-author of k .

If such a web service is implemented, it can be asked to the author if his/her proposed ranking with respect to the one of his/her co-authors in terms of "scientific diversity" seems to him/her relevant or not? This will be, in my opinion, a good way to evaluate if the proposed indicator gives information that fits with the general opinion. If some variant of the above definition are proposed, it can be checked which definition better indicates the scientific diversity.

5 Central journal of a publication list

One can also use the similarity matrix to define for any list L the central journal by looking which journal in the list $J(L)$ maximise the similarity with

$$\bar{j}(L) = \{j \in J(L) \text{ s.t. } \sum_{i \in L} S(j, j(i)) \frac{p(i)}{N(K(i))} = \max_{j' \in J(L)} \sum_{i \in L} S(j', j(i)) \frac{p(i)}{N(K(i))}\}.$$
 (3)

In other words, if we interpret similarity as the inverse of a pseudo distance, the central journal is the one that will minimize the average distance with the other in the list $J(L)$. This may be related to the Fermat-Weber point of Fréchet mean.

It may be interesting to rank the journals of the list by decreasing value of their averaged similarity with others (as defined above). It should give at the top of the list, the journals that correspond to the principal domain of the author or list and, at the end, the journals that are scientifically far from his/her speciality.

As for the comparison of the scientific diversity (SD) of his/her co-authors, one can think to ask, for such web service, if the ranking correspond to what is usually admitted (using a pool, and eventually, comparing the results of other definition).

One other possible service that can be useful for scientist is to propose some journals in which they never have published but which are "close" in the sense that the similarity is high with their central journal (one can restrict the suggestions of paper in the list of journals where their co-authors have published). This can suggest to enlarge their list of journals and avoid scientific concentration.

It is also possible to give information about the evolution of their scientific diversity over years. Note that this definition of a "central journal" is only an example of the use of the similarity index between journals and lot of other concepts can be proposed using tools of graph theory, network analysis, clustering...

Once again, feedbacks are welcome !

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