Eigenfactor: ranking and mapping scientific knowledge

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Abstract

For decades, citation counts and impact factor scores have been the primary currency for evaluating scholarly journals. While these measures have the virtue of simplicity, they discard much of the useful information that is inherent in the structure of citation networks. We therefore propose using the Eigenfactor algorithm (http://www.eigenfactor.org/methods.htm), which takes into account not only how many citations a journal receives but also where those citations come from. This is similar to how Google ranks web pages, but instead of ranking websites, we rank journals and instead of using hyperlinks, we use citations. This approach to bibliographic data also allows us to map scientific communication over time. This can be a useful tool for placing a journal in the context of the rest of science. We understand, though, that no metric or statistical tool will ever replace reading papers as the best form of evaluation. However, with the increasingly limited time and limited budgets of librarians, journal publishers, editors and scholars, there will continue to be a legitimate need for quantitative measures of the scholarly literature. We consider that, in this regard, the Eigenfactor is a step in the right direction.

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Jevin West is an ARCS Fellow in the Department of Biology at the University of Washington. His general research focus is mathematical biology. Specifically, he is interested in network theory and its application to a wide range of problems in biology including antibiotic resistance and disease evolution. His quantitative approach to biology has led him in all sorts of different research directions in other fields as well, including the field of bibliometrics. He is the head developer of Eigenfactor.org - a free website that provides tools and resources for librarians, journal editors, researchers and publishers to assess the ever-expanding scientific literature. Jevin has spoken about Eigenfactor at Harvard, Stanford, the European Science Foundation, SLA, ALA, the Council of Science Editors and the National Academy of Sciences.

Introduction

Assessment of academic journals began in 1927 at a small college in Southern California called Pomona College. Librarians there faced a problem that is even more challenging for today's librarians as the literature continues to expand while funding decreases. This forces the question: What journals should librarians buy?

In 1927, two chemists at Pomona College came up with the then novel technique of counting citations. However, simply counting citations is not necessarily the best way to rank journals. In 1955, therefore, Eugene Garfield devised the Impact Factor, which provided a better method of deciding which journals to buy. Currently, the Impact Factor drives several areas of academic decision making including hiring decisions, library subscriptions, promotion and tenure, advertisement placement, research funding for those who come under the standard Research Assessment Exercise in the United Kingdom, and university rankings.

As a result, the Impact Factor, which was originally intended to serve scientists, has become a tool over which scientists obsess, as do journal editors and publishers and academic administrators. In other words, the tail is wagging the dog instead of the other way around. As a result, there have been several articles published recently about how to redress the situation. The question that drives a lot of our research is how we can better evaluate the scholarly literature.

Investigating new methods of literature evaluation

The best method of evaluation is of course to read the literature, but no-one has the time for that. There is therefore a legitimate need for a better quantitative measure both because of restrictions in time and budgets, but also because of overuse of the Impact Factor.

We want to be able to answer questions such as: What is the value of a full volume of science? How often do biologists cite economics papers? Which publishers' bundles provide the best value? The latter is an issue that is at the forefront of librarians' decisions on which journals to buy.

In attempting to develop a new metric for journal evaluation, we first established the following set of criteria:

- It should be freely available – a new bibliometric measure should be open and able to be replicated.
- It should integrate many of the databases that exist today but did not exist yesterday.
- It should be valid across fields. One of the weaknesses of the Impact Factor is that it is not valid across fields because there are different citation cultures; for example, in mathematics, the typical number of citations in a paper is less than 20, whereas in biochemistry a typical paper has 60 citations.
- It should be robust against cheating.
- It should be maximally informative, using the most current algorithms and methods from information theory and network science.

We think that the Eigenfactor is a step towards meeting these criteria.

Figure 1 explains one of the major differences between the Impact Factor and the Eigenfactor.

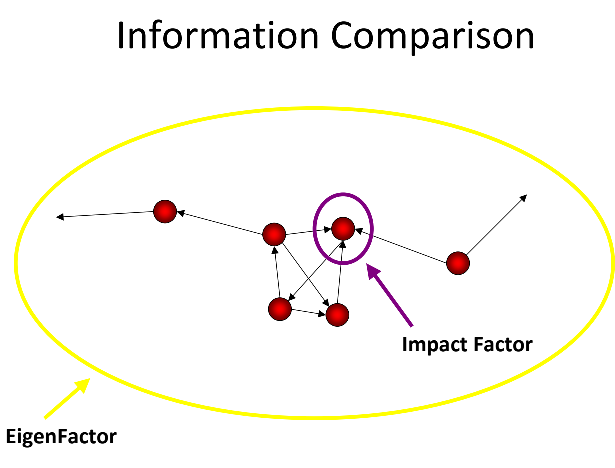


Figure 1: Differences between Impact Factor and Eigenfactor

For almost a century, we have been counting citations, which is the basis of Impact Factors. In contrast, the Eigenfactor takes into account the entire network and looks at the structure of the network. Thus, it takes into account indirect effects. To put it another way, Impact Factor measures just look at the arrows coming in, but do not account for where those arrows are coming from and thus ignore a lot of important information in the network. The Eigenfactor actually takes into account the entire network, whereas the Impact Factor only looks at small sections of the network.

What does the Eigenfactor represent?

The engine behind the Eigenfactor algorithm is a concept called Eigenvector centrality which was introduced by Bonacich in 1972. An example of an application of Eigenvector centrality is Google's PageRank Algorithm. The Eigenfactor and the PageRank Algorithm are very similar, but instead of ranking websites, the Eigenfactor ranks journals and instead of using hyperlinks from the web it uses citations from journals.

What does the Eigenfactor actually represent? If, for example, a researcher went into a library and randomly selected a journal, then randomly selected a citation and followed that to the next journal and repeated this process over and over, he/she could do it for infinity. The process can be modeled mathematically, which is essentially what the Eigenfactor does.

After this infinite process, the question is: Where does our researcher spend his or her time in the long run? By assessing this, the Eigenfactor measures total value. Librarians are typically interested in this particular value because they want to find out how long researchers would spend using particular journals if they were allowed just to walk randomly around the library.

We have another measure in addition to the Eigenfactor Score because researchers are interested in how much value a particular journal has per paper. Essentially, we take Eigenfactor and divide it by the number of articles, which gives us Article Influence. Article Influence is a measure that is more comparable to the Impact Factor. There exists, however, differences between the two measures in how certain fields are evaluated. Fields such as mathematics and economics rank relatively higher under Article Influence when compared to Impact Factor. However, in fields such as medicine there is a high correlation between the two measures.

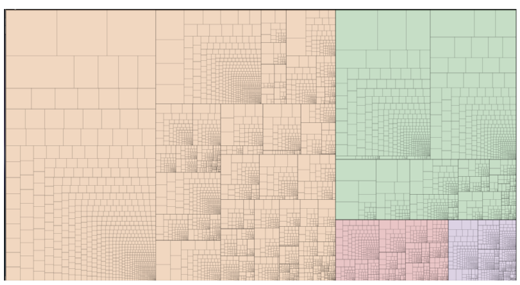
Characteristics of the Eigenfactor

The characteristics of the Eigenfactor metrics include the following. Citations from good journals are worth more, which is again similar to the way Google ranks web pages, and citations from non-reviewed journals are worth more. Citations from "frugal" fields, such as mathematics and economics that typically receive a lower Impact Factor, are ranked higher relative to impact factor.

The measure also enables evaluation of journals that typically do not get evaluated. We call this the grey literature. There are well over a 100,000 different scholarly publications that do not typically get ranked, but that can now be ranked with the Eigenfactor.

The Eigenfactor is also additive, which is a really important characteristic. One of the advantages of this measure is that just adding up the Eigenfactor Scores for each journal gives an approximation of the group of journals. Each square in the graphic below is a particular journal. At the bottom is the field of economics and at the top, as might be expected, are the journals Nature and Science.

Eigenfactor is additive



Because the measure is additive, we can evaluate bundles of journals using our cost effectiveness tool. Librarians are interested in not only the value based on citations, but also the value based on cost. To assess this, we take the Eigenvector and divide by the cost.

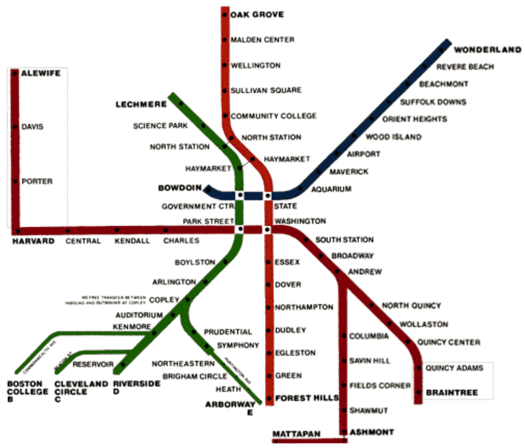
On our website, a researcher can search by fields or click on an individual journal and find a wide variety of information, including trends in data, pricing information, profit status, which group it is in and its percentile in all of science based on the metrics we have.

There are two different measures, the Article Influence Score and the Eigenfactor Score. It is possible to search by either depending on the kind of questions being asked about the value of a journal (total value use Eigenfactor Score; value per article use the Article Influence Score). For example, in terms of cost effectiveness, we have tools that show the total Eigenfactor Score that a group of journals would provide and the cost of that bundle. These tools are becoming very popular with librarians.

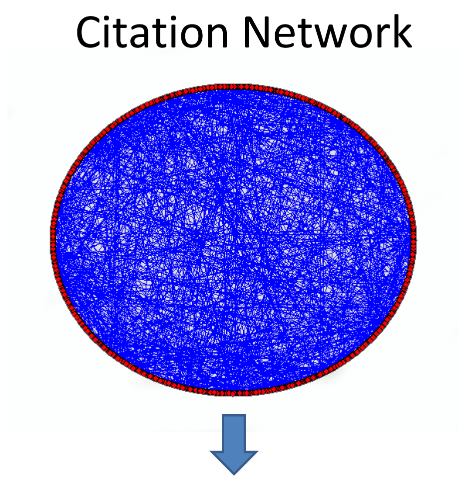
Another useful tool is the bubble charts at Eigenfactor.org. The bubble chart can show, for example that branding matters with journals. For example, some well-known publishers have begun to take over specific fields (see bubble chart on web). Some journals are not increasing their total number of articles, but they are increasing in value, which is what you want as an editor or publisher. Typically, a journal will increase its total articles to increase its value, but it turns out that if a journal is increasing its value without increasing its articles, it is doing really well. All of these tools and information can be viewed freely on our website.

Use of mapping

Another aspect of our work involves mapping of science. We are interested in using the tools from Network Science to map what has happened to science over the last 100 years. Biologists are very familiar with networks, such as yeast networks. In fact, they are inundated by such data and it is the same in the bibliometric literature or bibliometric field. However, we can take a model or picture and turn it into a map. For example, a Google picture of Boston is of little use for finding the route from Boston Airport to Harvard University because there is too much detail. A map, like a subway map, which compresses this information, is much better for this task.

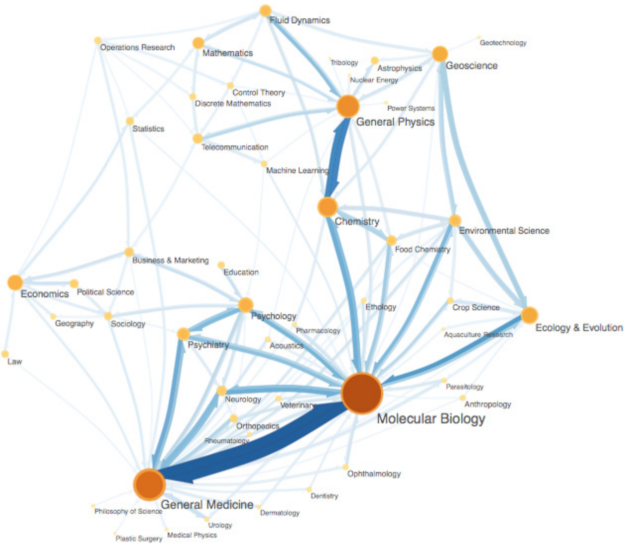


Similarly, we are trying to create maps instead of pictures and we have done the same thing with the citation network.



$$L(M) = q_{\curvearrowright} H(Q) + \sum_{i=1}^{m} p^{i}_{\circlearrowright} H(P^{i}).$$

We used an algorithm from information theory to create one of our first maps, the map of science.



Using an information-theoretic algorithm, the circles represent the amount of time that a researcher would spend in all of science in molecular biology if he/she was randomly walking around the literature. The edges represent the amount of flow of citations going from, for example, General Medicine to Molecular Biology. The boundary of the circles represents the amount of flow going out of that particular field. Usually, citations stay within the field, but sometimes a flow goes outside of the field as well.

A number of maps of citation data are being produced at present, but one of our main goals are to use these maps as a tool for evaluation and also as a way of looking at what is happening in science in particular fields over time. On our website, it is possible to navigate through a map of science. Eventually we want to be able to go down to individual articles. The arrows represent flow and in some fields, for example, ecology and evolution, typically only target analytical chemistry and not vice versa. Thus the map allows probing for of questions like how are fields related? Where is the flow of ideas going to and coming from? These are the types of questions that can be asked. There are also journals in each of these fields that can be clicked on for more information. It is possible to add or take away details from the map, just as with a regular map.

Conclusion

The main idea behind the Eigenfactor Project is that the tools we have been developing in network science and biology can be applied in the same way to many other data sets. There is a wealth of information in these data sets and our challenge is to develop algorithmic and visual tools to extract that information for librarians, publishers, editors, researchers, and anyone involved in the scholarly enterprise. One of the main goals of the Eigenfactor Project is to eventually use these tools to develop better ways to search through the literature for research and thus enable researchers to find out which papers they should be reading.

Acknowledgements

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