Versatile weighting strategies for a citation-based research evaluation model

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- 1 The Problem
- 2 Common metrics
- 3 The model
- Weighting strategies





- Number of scientific journals and papers is increasing at an almost exponential rate
- What to read? What to cite? Which journals subscribe? How to evaluate research?
- This burden affects researchers, funding agencies, university administrators, reviewers

Difficult to give an in-depth evaluation of the research
Use indirect indicators of quality





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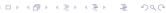




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Most of "automatic" methods rely on citation analysis

- Is a citation always a trusting vote?
- Data source and coverage
- How do authors choose the papers to cite?
- ... but also some pros
 - Peer review is not always practicable
 - There are plausible assumptions underlying the use of citation analysis as a heuristic
 - Simple and objective



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- Count the number of distinct authors who are citing me.





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- The ranking of papers and authors follows from the rank of the journals where the research is published

We proposed an integrated ranking of authors, journals, papers, areas, and institutions





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- Hiring in University or in a Industrial context
- Choosing individuals for a research team
- Many others ...

We try to design a tunable method to capture the different needs





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C is a $n_p \times n_P$ binary matrix describing the citation process

$$C(p_i, p_j) = 1$$
 iff p_i cites p_j

K is a $n_A \times n_P$ binary matrix describing authorship

$$K(a, p) = 1$$
 if author a has written paper p

F binary matrix $n_J \times n_P$

$$F(j, p) = 1$$
 if journal j publishes paper p





The system is represented by the matrix

$$S = \begin{bmatrix} FCF^T & FK^T & F \\ KF^T & KK^T & K \\ F^T & K^T & C \end{bmatrix}$$





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The matrices in the first column contribute to the ranking of journals



Weighting strategies



$$S = \begin{bmatrix} FCF^T & FK^T & F \\ KF^T & KK^T & K \\ F^T & K^T & C \end{bmatrix}$$

The matrices in the second column contribute to the ranking of authors





The system is represented by the matrix

$$S = \begin{bmatrix} FCF^{T} & FK^{T} & F \\ KF^{T} & KK^{T} & K \\ F^{T} & K^{T} & C \end{bmatrix}$$

The matrices in the third column contribute to the ranking of papers





Let P be a stochastic matrix "obtained" from S.

Working with a stochastic matrix guarantees that the amount of importance in the system is neither created nor destroyed.

Let

$$\pi = [\pi_J, \pi_A, \pi_P]$$

be the Perron vector of P, that is

$$\pi^T = \pi^T P,$$

The rank value of each subject is the value of the corresponding entry in π .





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Existence and uniqueness of the Perron vector is forced into P.

We make the nine blocks row-stochastic

We combine them into a larger stochastic matrix adding weights.





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$$P = \begin{bmatrix} \gamma_{1,1}A_{1,1} & \gamma_{1,2}A_{1,2} & \gamma_{1,3}A_{1,3} \\ \gamma_{2,1}A_{2,1} & \gamma_{2,2}A_{2,2} & \gamma_{2,3}A_{2,3} \\ \gamma_{3,1}A_{3,1} & \gamma_{3,2}A_{3,2} & \gamma_{3,3}A_{3,3} \end{bmatrix}$$

```
\pi_{J} = \gamma_{1,1}\pi_{J}A_{1,1} + \gamma_{2,1}\pi_{A}A_{2,1} + \gamma_{3,1}\pi_{P}A_{3,} 

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$$\begin{array}{ll} \pi_J &= \gamma_{1,1} \pi_J A_{1,1} + \gamma_{2,1} \pi_A A_{2,1} + \gamma_{3,1} \pi_P A_{3,1} \\ \pi_A &= \gamma_{1,2} \pi_J A_{1,2} + \gamma_{2,2} \pi_A A_{2,2} + \gamma_{3,2} \pi_P A_{3,2} \\ \pi_P &= \gamma_{1,3} \pi_J A_{1,3} + \gamma_{2,3} \pi_A A_{2,3} + \gamma_{3,3} \pi_P A_{3,3} \end{array}$$





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The three class model

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The weights γ_{ij} can be used to tune how much of their importance each player transfers to the subject.

Let

$$\mu_J = \sum_{i=1}^{n_J} \pi_i, \quad \mu_A = \sum_{i=n_J+1}^{n_J+n_A} \pi_i, \quad \mu_P = \sum_{i=n_J+n_A+1}^{n_J+n_A+n_P} \pi_i,$$

be the "energy" of each class





From the Coupling Theorem $\mu=[\mu_J,\mu_A,\mu_P]$, is such that $\mu^T=\mu^T\,\Gamma.$

How to choose Γ?





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How to choose Γ ?





Uniform weights, i.e.

$$\Gamma = \left[\begin{array}{ccc} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{array} \right],$$

we get $\mu = 1/3[1, 1, 1]$.





If $\mu=1/3\,[1,1,1]$, the mean value of a generic subject in a class is

$$\mathcal{M}_C = 1/3 \frac{1}{n_C}, \quad C \in J, A, P$$

In practical situation $n_J << n_A << n_P$, hence

$$\mathcal{M}_J >> \mathcal{M}_A >> \mathcal{M}_P$$
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Journals are much more important than papers and authors!





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Balancing weights

We want to find a possible Γ such that

$$\mathcal{M}_J = \mathcal{M}_A = \mathcal{M}_P$$
.

It is easy to prove that

$$\Gamma = \frac{1}{N} \begin{bmatrix} n_J & n_A & n_P \\ n_J & n_A & n_P \\ n_J & n_A & n_P \end{bmatrix}$$

is such that

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The rank value of each subject is obtained combining too many ingredients!



