Versatile weighting strategies for a citation-based research evaluation model

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The Problem

- 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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Most of “automatic” methods rely on citation analysis

The evaluation of research using citation analysis has weaknesses...

- 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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Common metrics:

Different metrics for different purposes

- Ranking journals - Libraries, scholars for deciding where to publish, ...
- Ranking papers - What to read, what to cite, ...
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- In the classical approach the ranking of journals is based on citations
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We proposed an integrated ranking of authors, journals, papers, areas, and institutions

Mutual reinforcement between papers, journals, authors

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General principles

- A paper is important if published in an important journal but also if cited by important papers and authored by important authors
- An author is important if she has important co-authors and has written important papers published in important journals
- A journal is important if collects citations from important journals, publishes important papers by important authors

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J	citation	publication	publication
A	publication	co-authorship	authorship
P	publication	authorship	citation

The three class model

Each paper can be described by means of

- List of authors
- Name of the journal
- List of references

Let n_P be the number of papers, n_A the number of authors and n_J the number of journals.

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The three class model

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

$$C(p_i, p_j) = 1 \text{ iff } p_i \text{ cites } p_j$$

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

$$K(a, p) = 1 \quad \text{if author } a \text{ has written paper } p$$

F binary matrix $n_J \times n_P$

$$F(j, p) = 1 \quad \text{if journal } j \text{ publishes paper } p$$

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

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

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

The three class model

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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We make the nine blocks row-stochastic

We combine them into a larger stochastic matrix adding weights.

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

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

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Weighting strategies

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

Weighting strategies

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

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How to choose Γ?

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How to choose Γ?

Uniform weights

Uniform weights, i.e.

$$\Gamma = \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix},$$

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

Uniform weights

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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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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Note that although it is possible to know in advance the average value of a particular class by looking at Γ, we cannot predict or influence the outcome of the algorithm.

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