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Research Article

A Modified Nature Publishing Index via Shannon Entropy

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This paper develops a Shannon Entropy approach based only on the number of papers published to propose scientific institution rankings. A simple and efficient approach with weight restrictions is employed to derive the score under specific preferences. The importance degrees for each preference are determined using the concept of Shannon Entropy. Finally, a weighted linear combination of different lexicographic preferences with subjective perceptions between the corrected count and the number of articles criteria is proposed. An application to Asia-Pacific ranking of the Nature Publishing Index is to illustrate the effectiveness of our proposed method.

1. Introduction

Studies that evaluate and rank the scientific institutions and countries are prevalent nowadays. The Nature Publishing Index (NPI), released by Nature Publishing Group (NPG) annually, ranks scientific institutions based only upon the number of primary research articles published in Nature and its family of Nature-branded sister journals. These high quality journals are world-renowned as the preeminent platform and also serve as the benchmark for research success and achievement. Two criteria, namely, the corrected count and the number of articles, are evaluated to constitute the NPI.

The corrected count is a score taking into account the number of affiliated scientific institutions per author and the percentage of authors per institution, which definitely is a decimal fraction with a maximum of one calculated for each paper for a given institution or for a given institution or country affiliated with the paper. All authors are deemed to contribute equally to the article, and an author with multiple affiliations is assumed to contribute equally to each affiliation.

The number of articles reflects the total number of articles with which a typical institution or country is affiliated according to the presented affiliations of authors in each publication. Institutions or countries are only counted once for a particular article. The rule governing the number of articles is that the advance online papers are not counted until the issue and page numbers have been assigned.

The quasi-official ranking published by NPG relies only on the lexicographic preference of corrected count. However, this is not to say that the number of articles is free from contention. Each institution or country will highlight what suits itself best. One particular institution or country may depend heavily on the corrected count, and another may prefer article counting. Therefore, the inconsistence of these two criteria to perceptions and other associated bias inevitably reduce the utilization and acceptance of the NPI.

In this paper, we are engaged in the tremendous surge in the interest in literature and stakeholders who have not been convinced about the existing approaches to develop better-accepted approaches to rank scientific institutions. An alternative approach based on the concept of Shannon Entropy is introduced to modify the quasi-official ranking of scientific institutions of the NPI. The conventional wisdom usually derives scores by assigning weights for each criterion, respectively. However, the proposed approach improves the original ranking by proposing a weighted linear combination of different lexicographic preferences with subjective perceptions between the corrected count and the number of articles criteria. The inconsistent preferences between the aforementioned two criteria are not uncommon in practice. More specifically, the quasi-official ranking released by NPG prefers the corrected count to the number of articles. However, on the other hand, the traditional method relies heavily on paper counting [1]. Because it considers both the corrected count and the number of articles, the proposed approach based upon Shannon Entropy improves the quasi-official ranking presented by NPG and is better than the original method at discerning the importance degree of each preference. The most similar idea to our paper is the "h-index" presented by Hirsch [2], which depends on both the number of a scientist's publications and their impact on his or her peers, and is recommended to inform research funding and tenure decisions [3].

The rest of this paper proceeds as follows. The proposed ranking method is introduced in Section 2. The application of our ranking method to Asia-Pacific ranking of the NPI is demonstrated in Section 3. Concluding remarks are presented in Section 4.

2. The Proposed Ranking Method

In this section, we first investigate the solution scheme with particular lexicographic preferences between the corrected count and the number of articles criteria and then propose a weighted linear combination of different lexicographic preferences based upon the concept of Shannon Entropy, the weights of which can be represented by relative importance degrees of the preferences.

2.1. Solution Scheme. For the multiple criteria decision making problem, Ng [4, 5] improves the work of Pearman [6] by defining a nonnegative weight w_{ij} for the decision making unit (DMU) i under criterion j (hereafter called the Ng model). Mild weight restriction to reflect the ranking of the importance of the criteria to the decision maker has been assumed to derive the scores for any DMU i; that is, $w_{i1} \geq w_{i2} \geq \cdots \geq w_{iJ}$. The score of DMU i is denoted by a weighted sum of performance measures under multiple criteria. Let y_{ij} be the performance of DMU i in terms of criterion j, which are transformed to 0-1 scale for comparable purpose,

$$\frac{y_{ij}}{\sum_{i=1}^{I} y_{ij}}. \tag{1}$$

Therefore, the Ng model for aggregation purpose is presented as

$$\begin{aligned} \max \quad & S_i = \sum_{j=1}^{J} w_{ij} y_{ij} \\ \text{s.t.} \quad & \sum_{j=1}^{J} w_{ij} = 1 \\ & w_{ij} \geq w_{i(j+1)} \geq 0, \quad j = 1, 2, \ldots, J-1 \\ & w_{ij} \geq 0, \quad j = 1, 2, \ldots, J. \end{aligned} \tag{2}$$

By employing the following transformations, namely, $u_{ij} = w_{ij} - w_{i(j+1)}$, $u_{iJ} = w_{iJ}$, and $x_{ij} = \sum_{k=1}^{j} y_{ik}$, the above model (2) is converted to the following formulations for each DMU i:

$$\begin{aligned} \max \quad & S_i = \sum_{j=1}^{J} u_{ij} x_{ij} \\ \text{s.t.} \quad & \sum_{j=1}^{J} j u_{ij} = 1 \\ & u_{ij} \geq 0, \quad j = 1, 2, \ldots, J. \end{aligned} \tag{3}$$

One can easily obtain the maximal score S_i by the dual of (3), which is

$$\begin{aligned} & \min z_i \\ & z_i \geq \frac{1}{j} x_{ij}, \quad j = 1, 2, \ldots, J. \end{aligned} \tag{4}$$

Finally, the maximal score S_i can be derived as $\max_{j=1,2,\ldots,J}\{(1/j) \sum_{k=1}^{j} y_{ik}\}$.

Therefore, an integrated scoring scheme based upon the aforementioned Ng model can be employed to derive scores for each of the preferences, namely, the correct count ≻ the number of articles (hereafter called as P1) and the number of articles ≻ the correct count (hereafter called as P2).

2.2. A Shannon Entropy Approach. Shannon Entropy [7] plays a fundamental role in information theory, which is also a useful and effective mathematical tool to measure uncertainty. Employing Shannon Entropy as a coefficient of importance degree is pioneered by Zeleny [8] in multiple criteria decision making. The present section aims at providing a Shannon Entropy approach to evaluate the importance degree of each preference and then combine the results derived from the above two lexicographic preferences. Common weights represented by the importance degrees are determined for each of the preferences, respectively.

The motivations for using Shannon Entropy to modify the quasi-official ranking provided by NPG are summarized in the following three aspects.

(1) The discriminatory powers of the above two preferences are different, and it is difficult for us to determine a widely accepted ranking.

(2) Each of the aforementioned preferences evaluates the DMUs from a different perspective and definitely has some valuable advantages which we could not ignore.

(3) Any single preference has limited discriminatory power in evaluating and ranking; therefore, it is suitable to integrate different preferences into evaluation simultaneously.

We firstly summarize the results obtained from the different preferences for the scientific institution in the following matrix, where the first column represents the scores obtained

Table 1: Result comparisons.

Rank	Institutions	Corrected count	Articles	Ng model		Our results	New rank	Rank difference
				P1	P2			
1	CAS, China	69.44	212	0.1114	0.1060	0.1082	1	**0**
2	The University of Tokyo, Japan	48.58	128	0.0779	0.0694	0.0728	2	**0**
3	RIKEN, Japan	30.77	102	0.0493	0.0489	0.0491	3	**0**
4	Kyoto U, Japan	26.35	69	0.0423	0.0375	0.0394	5	−1
5	NUS, Singapore	22.07	87	0.0384	0.0413	0.0401	4	+1
6	UQ, Australia	19.83	69	0.0323	0.0328	0.0326	8	−2
7	Osaka U, Japan	19.74	62	0.0317	0.0306	0.0310	10	−3
8	PKU, China	19.66	79	0.0345	0.0375	0.0363	6	+2
9	SNU, South Korea	17.47	51	0.0280	0.0261	0.0269	11	−2
10	Tsinghua U, China	17.05	68	0.0298	0.0323	0.0313	9	+1
11	NTU, Singapore	15.07	41	0.0242	0.0218	0.0228	13	−2
12	The University of Melbourne, Australia	13.83	80	0.0301	0.0380	0.0348	7	+5
13	USTC, China	13.49	39	0.0216	0.0201	0.0207	16	−3
14	Nanjing U, China	12.93	33	0.0207	0.0182	0.0192	19	−5
15	SJTU, China	12.46	40	0.0200	0.0195	0.0197	18	−3
16	Fudan U, China	11.85	50	0.0214	0.0238	0.0228	12	+4
17	Tohoku U, Japan	11.61	44	0.0198	0.0209	0.0204	17	**0**
18	ANU, Australia	11.24	39	0.0183	0.0185	0.0184	20	−2
19	Monash U, Australia	11.09	50	0.0208	0.0238	0.0226	14	+5
20	Tokyo Institute of Technology, Japan	10.54	28	0.0169	0.0151	0.0158	26	−6
21	Nagoya U, Japan	10.52	31	0.0169	0.0158	0.0162	23	−2
22	KAIST, South Korea	10.49	34	0.0168	0.0165	0.0166	22	**0**
23	ZJU, China	10.05	37	0.0168	0.0176	0.0173	21	+2
24	A∗STAR, Singapore	10.04	48	0.0195	0.0228	0.0215	15	+9
25	POSTECH, South Korea	9.04	26	0.0145	0.0134	0.0139	30	−5
26	Kyushu U, Japan	8.72	30	0.0141	0.0143	0.0142	29	−3
27	The University of Sydney, Australia	8.63	35	0.0152	0.0166	0.0161	25	+2
28	BGI, China	8.6	33	0.0147	0.0157	0.0153	27	+1
29	NTU, Taiwan	8.59	25	0.0138	0.0128	0.0132	31	−2
30	HKUST, China	7.95	12	0.0128	0.0092	0.0106	38	−8
31	NIMS, Japan	7.71	28	0.0128	0.0133	0.0131	32	−1
32	NTT Group, Japan	7.17	11	0.0115	0.0084	0.0096	41	−9
33	Keio U, Japan	6.92	22	0.0111	0.0108	0.0109	37	−4
34	UNSW, Australia	6.69	37	0.0142	0.0176	0.0162	24	+10
35	CSIRO, Australia	6.58	34	0.0134	0.0162	0.0150	28	+7
36	AIST, Japan	6.57	21	0.0105	0.0103	0.0104	39	−3
37	CAMS & PUMC, China	6.21	28	0.0116	0.0133	0.0126	33	+4
38	IISC, India	6.12	11	0.0098	0.0075	0.0084	47	−9
39	Hokkaido U, Japan	6.1	18	0.0098	0.0092	0.0094	44	−5
40	Academia Sinica, Taiwan	5.8	26	0.0108	0.0124	0.0117	34	+6
41	University of Tsukuba, Japan	5.77	15	0.0093	0.0082	0.0086	45	−4
42	Yonsei U, South Korea	5.71	26	0.0108	0.0124	0.0117	35	7

Table 1: Continued.

Rank	Institutions	Corrected count	Articles	Ng model P1	Ng model P2	Our results	New rank	Rank difference
43	Jilin U, China	5.44	16	0.0087	0.0082	0.0084	48	−5
44	NINS, Japan	5.27	18	0.0085	0.0086	0.0085	46	−2
45	Sun Yat-sen U, China	4.98	25	0.0099	0.0119	0.0111	37	+8
46	SKKU, South Korea	4.68	23	0.0092	0.0109	0.0102	40	+6
47	Macquarie U, Australia	4.56	21	0.0086	0.0100	0.0094	42	+5
48	JAMSTEC, Japan	4.52	14	0.0072	0.0069	0.0071	49	−1
49	Sichuan U, China	4.52	21	0.0086	0.0100	0.0094	43	+6
50	Huazhong Agricultural U, China	4.5	8	0.0072	0.0055	0.0062	50	**0**

from P1 and the second column shows the results from P2; the scores are derived by the presented Ng model in Section 2.1:

$$S_{I\times 2} = \begin{pmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \\ \vdots & \vdots \\ S_{I1} & S_{I2} \end{pmatrix}. \tag{5}$$

Note that the results derived from the Ng model are 0-1 scale. Therefore, for the purpose of comparing, the second column in matrix (5), namely, $S_{12}, S_{22}, \ldots, S_{I2}$, is transformed data according to (1).

In line with the work of Soleimani-Damaneh and Zarepisheh [9], we introduce the following five steps to determine the respective weights for both preferences P1 and P2 on the basis of Shannon Entropy.

Step 1. Normalize the matrix $S_{I\times 2}$ by $s_{ij} = S_{ij}/\sum_{i=1}^{I} S_{ij}$.

Step 2. Determine the entropy for each ranking; $f_j = -[\ln(n)]^{-1} \sum_{i=1}^{I} s_{ij} \ln(s_{ij})$.

Step 3. Calculate the degree of discriminability for each ranking as $d_j = 1 - f_j$.

Step 4. Compute the weight λ_j for the ranking system j, $j = 1, 2$ by normalizing d_j; that is, $\lambda_j = d_j/\sum_{j=1}^{2} d_j$.

Step 5. Calculate the overall scores for DMU i; $S_i = \sum_{j=1}^{2} \lambda_j S_{ij}$, $i = 1, 2, \ldots, I$.

3. Numerical Illustrations

For the purpose of demonstrating the usefulness of our proposed approach, we apply it to the Asia-Pacific ranking of the NPI released by NPG on 2014-10-20 listed in Table 1. The current index date range is from 2013-10-21 to 2014-10-20. These rankings only include articles published as research papers (articles, letters, and brief communications) or reviews in Nature and/or Nature monthly research journals.

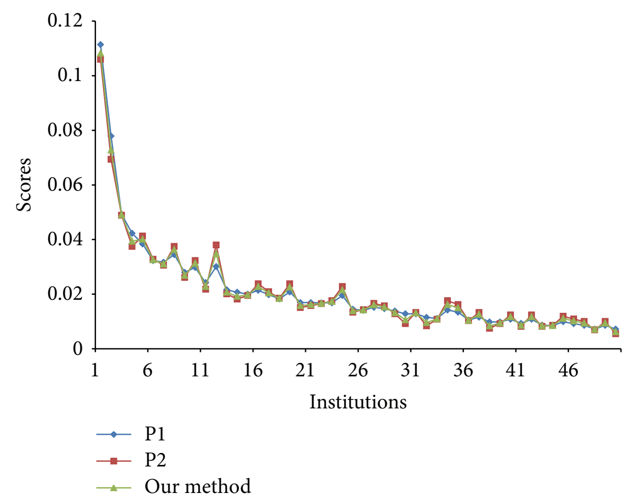

Figure 1: Comparisons among P1, P2, and our method.

We directly apply the Ng model to derive relative scores for both P1 and P2 and then calculate the final results according to our proposed method based upon Shannon Entropy, where the common weights for P1 and P2 are $\lambda_1 = 0.4018$ and $\lambda_2 = 0.5982$, respectively. Related results and some comparisons have been summarized in Table 1.

Compared with the quasi-official ranking released by NPG, 44 out of the 50 institutions are ranked differently. More specifically, 18 institutions are up-ranked while 26 institutions are down-ranked.

Figure 1 vividly compares the results among P1, P2, and our method, where we denote the institutions by the ranking position published by NPG.

4. Conclusions

In this paper, a Shannon Entropy approach based only upon the number of articles published by institutions has been developed to modify the quasi-official ranking released by NPG, which may face some problem to determine a widely accepted ranking for different preferences. This paper presents a model, which effectively determines the importance degree of two different preferences between the corrected count and the number of articles. The common weights are determined for these two preferences, respectively. The scores derived from the proposed method are calculated to provide a unique sequence of the institutions. The ranking method presented in this paper is originated from easily understood premises and provides interesting insights for ranking construction to avoid controversy. The results of numerical practice illustrate different perspective and discriminatory power of different preferences. In future, the method presented in this paper could be applied to other multiple criteria decision making problems, which should contain more than only two preferences discussed here. For more complex ranking and performance measurement problem, this method can also extend and exploit its discriminatory power.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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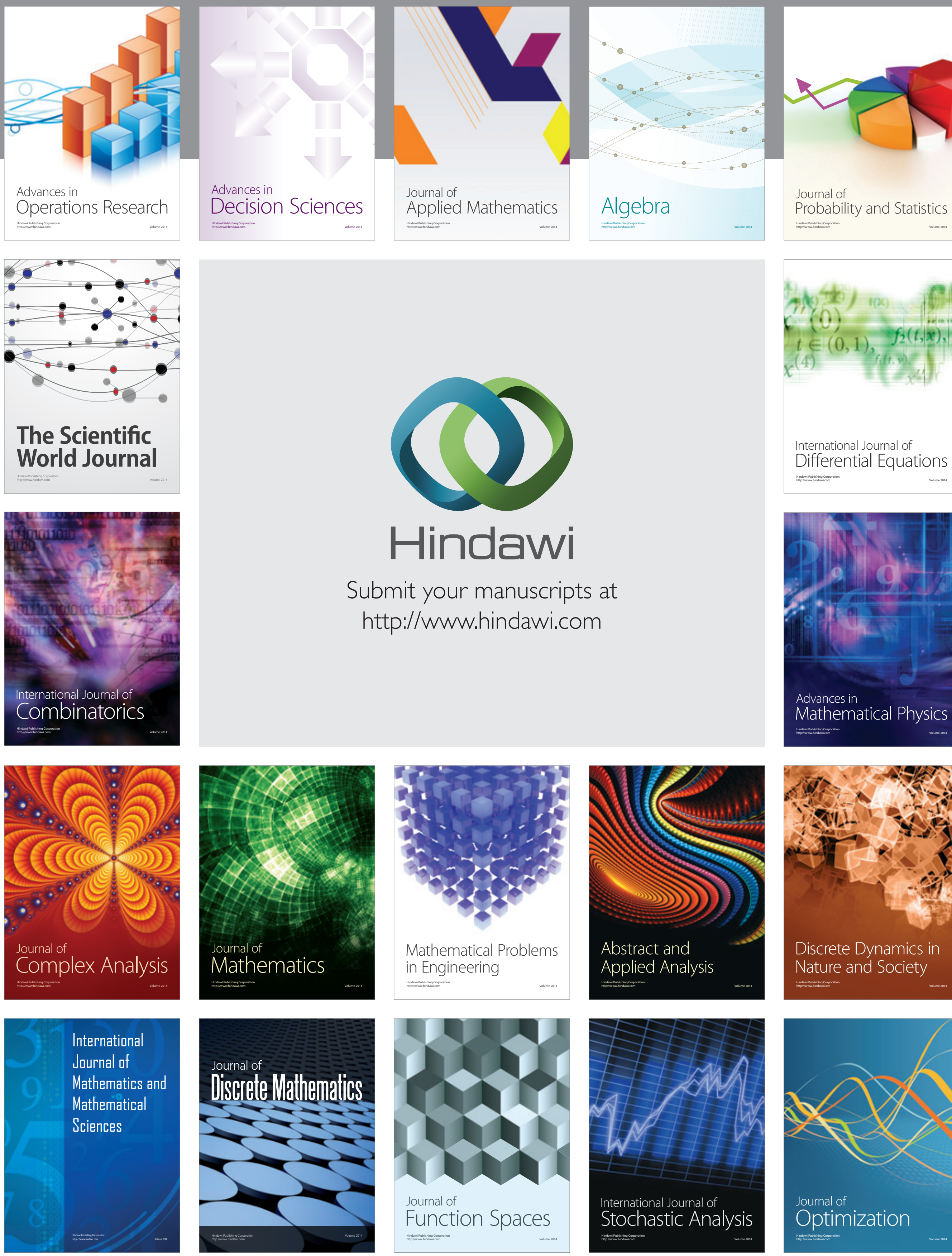
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