

A Neuro-Fuzzy System to Calculate a Journal Internationality Index

Pandelis Perakakis
Department of Psychology
University of Granada
peraka@ugr.es

Michael Taylor
Department of Theoretical Physics
Autonoma University of Madrid
michael.taylor@uam.es

Gualberto Buela-Casal
Department of Psychology
University of Granada
gbuela@ugr.es

Purificación Checa
Department of Psychology
University of Granada
checaal@ugr.es

Abstract

Internationality as a concept is being applied ambiguously and erroneously, particularly in the world of academic journal publication where it is often used as a quality indicator. Although different qualitative criteria have been used by scientometrists in order to attempt a measure of internationality in various contexts, it is now clear that the literal definition of internationality is a minimal one while other proposed measures based on individual criteria fail to provide a complete and accurate assessment. As such, internationality remains to be defined².

Here, we present a holistic approach to the problem based on fuzzy logic. We surveyed, critically-assessed and pruned the set of internationality criteria in the context of academic publishing, selecting those that are semantically precise and amenable to *quantitative* measure. We have tested the ability of each criterion to measure

internationality by applying them to four thematically-connected journals from the field of Health and Clinical Psychology, using descriptive statistics and the Gini Coefficient. The results of this case study revealed that, in the absence of a method of numerically weighting the criteria, any measurement of internationality remains ambiguous and incorrect.

We propose that internationality is best represented by a neuro-fuzzy system of fuzzy sets of the weighted criteria linked by fuzzy rules in a multi-layer perceptron, whose output defuzzification gives a new measure – a *Journal Internationality Index* akin to the Impact Factor for citations. Viewing internationality in this way as an approximated fuzzy function means a quantitative measure can be found while keeping intact its semantic rule origins and meaning.

1. Introduction

Although the technological developments in the electronic era have introduced new modes of interaction between scholars, publications in academic journals, in print form or on-line, remain a vital element in the process of academic communication, evaluation and quality indication (particularly publications in prestigious journals). Hence the need for carefully contemplated measures and quantitative indices to assess journal information.

Several such measures have been proposed, one of them being the *internationality* of a journal. Even though this is constantly receiving more attention in a world that is tending towards a globalisation of forces and ideas, journal internationality has still not been unambiguously defined. Thus, a *Journal Internationality Index*, akin to the Impact Factor for citations, would be an indispensable tool for authors, readers, editors, publishers and generally anyone interested in the evaluation of journals or their articles. In this paper, we outline a semantic and theoretical foundation for the development of such an index.

Section 2 introduces the notion of internationality as a fuzzy set. In section 3, we outline the contemporary view of internationality as reported in the literature and then present in section 4 an assessment of those criteria used to assess it. Since these criteria form the basis of the fuzzy sets and fuzzy rules at the core of the neuro-fuzzy system, we pay particular attention to clarifying them. In section 5 we show how, even after selective pruning of the criteria, they fail as individual measures of internationality when tested on a small set of carefully chosen and thematically-linked journals. This leads, in section 6, to our recasting of the problem of the quantitative measurement of internationality as a neuro-fuzzy system such that a semantically-meaningful and defuzzified value can be obtained in the form of a newly proposed Journal Internationality Index. We then conclude with a brief discussion of the approach and its potentiality of this method in other sociological contexts.

2. Internationality as a fuzzy set

When constructing a measure of internationality, the literal definition of the term “international” as “relating to, or affecting two or more nations”¹⁴ creates a problematic starting point. The bivalent nature of the definition (IS or IS NOT - based on the number two) means that it fails to describe the *degree* of internationality associated with a potentially diverse range of country representation in academic journals. Seen in this way, internationality, solely from the point of view of country representation, is already a fuzzy set. In fact, the degree of internationality ranges from the unusual case of a journal relating to or affecting only one nation (an entirely national project) to the more usual case of academic journals involving and affecting more than one nation (*ranging* from two to as many as 192 nations, i.e. the number of independent world states³) as illustrated in Figure 1.

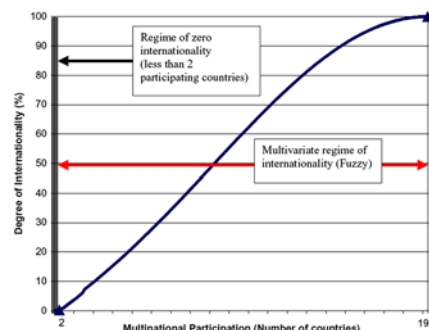


Figure 1. Internationality as a fuzzy set associated with the degree of geographical participation

The designation *international journal* is therefore imprecise in its literal sense, and incapable of differentiating quantitatively between, for example, a journal that circulates between two neighbouring countries and one with a global representation or impact.

As we show below, internationality depends on a number of criteria and therefore, we believe, is best viewed as a *multivalent* fuzzy variable that

operates within a definable range, but whose actual measure is variable.

3. The contemporary view of internationality

Further support for the need to define and use internationality as a fuzzy, multivalent concept is evidenced in the literature where the term international, referring or not to academic journals, is being used extensively without qualification. We were able to illustrate this point in a previous paper² where we conducted a literature research on some of the most important encyclopaedias and handbooks of Psychology including: the Encyclopedia of Psychology⁹, the International Encyclopedia of the Social and Behavioral Science¹, the International Handbook of Psychology¹⁷ and the Handbook of Psychology⁵. Our review revealed that, although the term international is broadly used, it is being done so without any reference to quantitative indices. Instead we mostly encounter the term in its literal sense, or with other subjective interpretations such as: “different countries”, “around the world” or “worldwide” etc.

Unquestionably though, when we refer to a journal, an association or an event with the characterization *international* we do not expect it to merely fulfil the literal definition. Rather, we assume that it enjoys a larger degree of multinational representation in terms of country participation and content. At the other extreme, we do not expect to meet people from *every* single country in the world when we attend an international conference. Therefore, it is evident that internationality is already understood (subjectively) as being a matter of degree and is intuitively perceived as a fuzzy concept, although we may lack the appropriate quantitative indices to objectively express it. Since this has wide applicability in many spheres that are considered to be international, the case for an Internationality Index is therefore both strong and urgent. We now

present the criteria used to assess internationality and which form the basis for the development of the Journal Internationality Index.

4. Internationality criteria

The assessment of internationality and, in particular, the internationality of academic journals, is not a new issue. Various attempts have been made in the past to classify and compare journals according to their internationality using quantitative indices. In these efforts scientometrists have used those individual criteria that they considered to be more important in the evaluation of journal internationality. Nevertheless, numerous criteria have been proposed and it is obvious that a complete and coherent description of internationality should consider all those criteria that are relevant. Fuzzy logic again provides the best theoretical framework since the various internationality criteria can be viewed as separate variables that influence the final internationality outcome *to some degree*. Below we list the internationality criteria that have been collated from the literature. A fully comprehensive discussion of the criteria may be found elsewhere². We argue that some of them do not play an important role in the assessment of internationality, propose additional criteria that we believe enhance and extend the set, and explain how no single criterion by itself is a sufficient measure of internationality.

4.1. Publication language

The publication language (or languages) is a choice that affects linguistic accessibility and therefore the journal's internationality due to the geographical distribution of readers. There is no doubt that a journal publishing in several languages is more international, in this sense, provided that it is born in mind that it should reflect international (cross-border) access.

4.2. Publication country

It is apparent that a journal's publication country does not affect its internationality and that a journal published in a foreign country is nothing more than a foreign journal. This then, is a criterion used by those who confuse "international" with "foreign".

4.3. Inclusion in international databases

This criterion is extensively used but is an unreliable measure of internationality since the journals *themselves* that are included in international databases such as PsycLIT, Medline, ERIC or Ingenta, are not necessarily international in nature. However, this criterion *does* affect the diffusion of knowledge and awareness of publications and therefore has a bearing on the multinational distribution of readers and journal users, and hence, on international accessibility.

4.4. The impact factor

It has been demonstrated⁶⁻⁸ that in most research areas, multinational collaboration results in greater visibility and higher citation rates. Thus, there is an empirically confirmed positive correlation between internationality, measured by multinational collaboration, and Impact Factor. However this does not mean that there is a causal relationship between citation impact and internationality. The inclusion of a journal in the catalogue of Journal Citation Reports, which automatically assigns to it an Impact Factor based on citation analysis, does not imply anything about internationality in terms of journal content or with respect to the multinational distribution of authors.

4.5. Affiliation to an international institute or association

Although, in principle, it seems logical that a journal published by an association with an international reputation would be an international journal, this again is not sufficient as it depends sensitively on the internationality of the parent institution or association.

4.6. Multinational distribution of the editorial board members

This refers to the international make-up of editorial boards and is another of the most commonly mentioned criteria referring to journal internationality¹⁸. Obviously, an editorial board comprising reviewers from various countries facilitates that the revision of the articles is made from a more international perspective, provided that the authors are drawn from an international pool. Furthermore, we make a new distinction between the permanent "in-house" editorial board and the pool of associate editors *selected* by the editorial board to review articles "out of house". These two groups are often lumped together under the term "editorial committee" in the literature.

4.7. Multinational distribution of the associate editors

The generally broader multinational distribution of these "out of house" editors means that they are more likely to represent a global perspective. However, since, in the majority of cases, their role is a secondary one with them reviewing articles selected by the editorial boards, the global filtering bias may have already been introduced at the primary level of the editorial boards.

4.8. Multinational distribution of authors

This is probably the most common measure of journal internationality. It has been argued²¹ that there are absolute and relative approaches to calculate internationality based on the multinational distribution of authors. The absolute approaches use concentration indices that consider the percentage of foreign authors in a journal's total output, ignoring each country's general academic contribution and therefore fail when this is an important factor. Other indices to evaluate relative internationality have also been proposed²¹, utilizing well-contemplated normalization options to avoid biases caused by the different national academic sizes in each area. Nevertheless, they also recognize the value of

reference-free, concentration indices in providing a wider perspective.

4.9. Multinational distribution of users

A journal's users are its readers, subscribers and citers. However, bibliometric research has direct access only to the geographical distribution of citers. Obviously, equating citers and users leaves out all readers that are not academic authors as well as the academics who are consulting journals outside their particular research area and so do not cite them in their work. Nevertheless, the majority of the studies that examined this criterion have done so through the analysis of the geographical distribution of citers, making the assumption that it reflects the actual multinational distribution of all journal users⁴.

4.10. International collaboration patterns

A journal's capability to attract multinational collaboration is another useful and extensively investigated criterion^{11, 12, 13, 15}. International collaboration is assessed by co-authorship indices that provide information about the share of internationally co-authored papers in a journal's total publication output¹³.

4.11. Online access

Since 1996, the vast majority of journals have online archives of their print articles, which would appear to increase global access. However, here, as for the criterion relating to publication language, there are other issues involved such as the dominant languages used in web pages and, in particular, economic accessibility associated with electronic journal subscription rates.

From the above list, it is clear that there are many criteria commonly used to measure the internationality of an academic journal. However, there are many ways to quantify these criteria since there are many normalization options and interdependencies, for example, between the publication language and the geographical

distribution of users. In the next section we prune and test a selected sub-set of criteria which should be used to form the fuzzy set basis.

5. Pruning and testing the criteria

Following the above analysis of the set of criteria, we identified the following sub-set as being the most semantically precise and amenable to *quantitative* measure: a) the multinational collaboration patterns, b) the multinational distribution of editorial board members, c) the multinational distribution of associate editors and d) the multinational distribution of authors.

In order to test this pruned list, we conducted a thorough bibliometric analysis on four psychology journals from the area of clinical and health psychology². We hypothesized that these criteria, being the most quantifiable and coherent, would still yield different measures of internationality when viewed individually and not as interconnected elements each having a different and carefully weighted influence.

The journals subjected to analysis were: the Journal of Clinical Psychology, Health Psychology, the International Journal of Clinical and Health Psychology and the International Journal of Psychology and Psychological Therapy. The material analyzed covered all articles published between 2001 and 2003 (inclusive) therein. For the analysis we used descriptive statistics and the Gini coefficient of inequality; such that a coefficient of 1 represents total inequality while 0 represents total equality.

Figure 2 presents as an example, the Pareto analysis on the multinational distribution of authors. As seen, all four journals have a high Gini coefficient reflecting their poor multinational distribution. However, the International Journal of Clinical and Health Psychology has a smaller coefficient and can thus be characterized as more international according to this criterion.

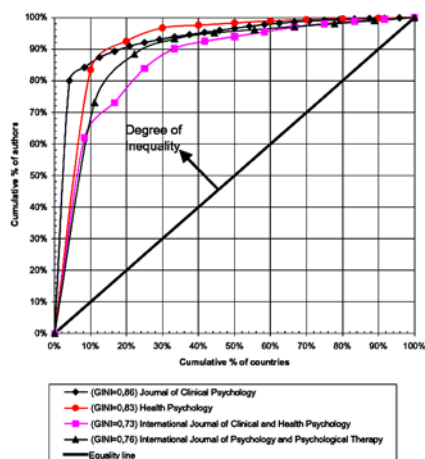


Figure 2. Pareto analysis and Gini coefficient measure of inequality of the global representation of authors

Figure 3 presents a summary of the journals' performance for each of the pruned criteria. The results show that the measure of internationality varies according to the choice of criteria.

Journal	Share of International Articles	Number of countries in the editorial board	Inequality in the distribution of editorial board members per country (Gini Coefficient)	Inequality in the distribution of authors per country (Gini Coefficient)
Journal of Clinical Psychology	7.43%	1 (USA)	0.75	0.86
Health Psychology	7.11%	-	-	0.83
International Journal of Clinical and Health Psychology	11.96%	3 (Spain, Portugal, Colombia)	0.65	0.73
International Journal of Psychology and Psychological Therapy	18.18%	5 (USA, Spain, Belgium, Ireland, Mexico)	0.75	0.76

Figure 3. Summary of the test results for the four thematically-linked journals (boxes highlight the most international)

This brief resume of the small-scale case study demonstrates that in the absence of a suitable method of weighting the pruned criteria, a complete and valid assessment of journal internationality is impossible. Below, we present a neuro-fuzzy system that can be used to assign fuzzy weights to the pruned criteria and to calculate a Journal Internationality Index using fuzzy logic rules and defuzzification.

6. A neuro-fuzzy system to calculate the Journal Internationality Index

In 1992, it was shown that fuzzy systems could be used for function approximation based on a set of semantic or linguistic rules¹⁰. The combination of this mathematical capability with the result that fuzzy systems could be represented as a mapping from input space to output space¹⁹, led to the notion of neuro-fuzzy systems for function approximation. In what follows, we cast the problem at hand as one whereby we wish to calculate the Journal Internationality Index as a function of relevant criteria upon which it is based using such a system. Figure 4 shows a schematic of the 3 layer feed-forward multi-layer perceptron proposed to solve the problem.

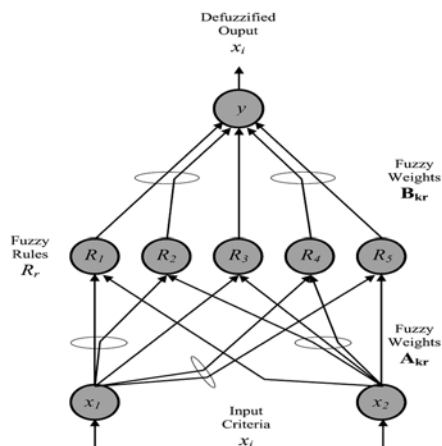


Figure 4. Schematic of the neuro-fuzzy system to be used to perform fuzzy function approximation (adapted from Nauck and Krause¹⁵)

A fuzzy logic system is an approximate system that models linguistically, as would be perceived by a person²⁰. A fuzzy logic system has a series of rules; each consisting of antecedents and consequents. The antecedents are a conjunction of input variables, qualified by fuzzy sets, and their associated membership functions. Consequents are also determinable degrees of

fuzzy sets that have certain qualified membership values, and represent the outcome(s) of the fuzzy rules in question. Traditionally fuzzy logic systems involve four key stages:

1. *Fuzzification*, where input variables are qualified by their corresponding fuzzy sets
2. *Inferencing*, where fuzzy set values are combined per rule, based on operators linking the input variable, fuzzy set pair
3. *Composition*, where the consequences derived by inferencing, are combined for the rule base
4. *Defuzzification*, where the composite value is converted to a real-world value

In order to construct our neuro-fuzzy system, we need to identify the membership functions (parameters) and a rule base (structure) for the problem. The first step lies in casting the pruned criteria as fuzzy sets²⁰. These provide the inputs to the network (x_i). The membership functions are the weightings of the antecedent fuzzified criteria (A_{rk}) represented by the strengths of inter-neuron links connecting them to the fuzzy rule hidden layer (R_r). The loops in figure 4 correspond to inferencing. The rule base is the network architecture which reflects inter-dependencies between the criteria and which is used to compose the fuzzy output from the consequent weights (B_{rk}). The fuzzy output set for a rule is implied as the coefficients of the input variables with each rule expressed as a linear equation. Finally, the defuzzified output is generated by a centroid method that divides the sum of products of rule strengths and dependent values of the linear equations by the sum of rule strengths. This step provides a discrete numerical value for the Journal Internationality Index. Learning of the network is achieved through the use of a large sample of data for the subjective weights of the criteria, partitioned so that verification may also take place. The learning procedure uses fuzzy error backpropagation¹⁶.

Since the neuro-fuzzy system has a generic semantic rule base, learning is expected to be simple and fast allowing the result to be easily interpreted for its meaning content. We would like

to stress that we have decided upon a fuzzy system since the subjective nature of internationality means that there is no exact solution (in the mathematical sense). We are then exploiting as fully as possible our tolerance for a holistic, meaningful and carefully-constructed, although mathematically imprecise solution.

In order to construct and test the neuro-fuzzy system, we are in the process of issuing a questionnaire to a large-scale sample (>1000 participants) including journal staff (also from open source journals), users and global academics in order to ascertain fuzzy sets for the weighting ranges for each pruned criterion. The sample are being asked to provide their subjective view on criteria weightings and interdependencies, and to suggest other criteria they believe to be relevant in order to further evolve the criteria list. We will then fuzzyify the problem in the criterion-internationality space with an evolved set of fuzzy rules to construct the neuro-fuzzy system. Defuzzification will then provide a value for the Journal Internationality Index which can then be used:

- a) to define internationality
- b) to re-assess journals and to compare with published Impact Factor rankings
- c) to argue for a reassessment of internationality in other (non-journal publishing) contexts

7. Conclusion

The term international is being used extensively in the context of academic journals, and moreover, often as a synonym for quality. In this regard, it is an issue in need of urgent clarification.

In the present paper we argue that internationality is best viewed as a complex construct resulting from the interaction of many interdependent fuzzy criteria sets (parameters), each having a different subjective weight with none sufficient in itself to account for all qualitative properties. Furthermore we have explained how the literal definition fails to describe the degree of internationality and we have presented a systematic approach that we

hope will reflect more accurately the degree of internationality.

In short, given that internationality represents a value judgment based upon many influencing and subjective criteria, casting it as a neuro-fuzzy system seems to offer the best way forward towards a first semantically-unambiguous and holistic definition of internationality and its quantitative measure in the form of the internationality index.

References

- [1] Baltes, P.B., Smelser, N.L (Eds), *International Encyclopedia of the Social and Behavioral Science*. Elsevier, 2001.
- [2] Buela-Casal, G., Perakakis, P., Taylor, M., Checa, P., Measuring Internationality: Reflections and Perspectives on Academic Journals, *Scientometrics*, (In press) .
- [3] Bureau of Intelligence and Research, Washington, DC. 2004; Available at www.state.gov/s/inr/rls/10543.htm.
- [4] Christensen, F.H., Ingwersen, P., Wormell, I., Online determination of the journal impact factor and its international properties, *Scientometrics*, 40 (1997) 529-40.
- [5] Freedheim, D.K., Weiner, I.B. (Eds), *Handbook of Psychology: History of Psychology*. John Wiley and Sons, 2002.
- [6] Glanzel, W., de Lange, C., A distributional approach to multinationality measures of international scientific collaboration, *Scientometrics*, 54 (2002) 75-89.
- [7] Glanzel, W., National characteristics in international scientific co-authorship relations, *Scientometrics*, 51 (2001) 69-115.
- [8] Glanzel, W., Schubert, A., Czerwon, H.J., A bibliometric analysis of international scientific cooperation of the European Union (1985-1995), *Scientometrics*, 45 (1999) 185-202.
- [9] Kazdin, A.E. (Ed), *Encyclopedia of Psychology*. Oxford University Press, 2000.
- [10] Kosko, B., Fuzzy systems as universal approximators, *In Proc. IEEE Int. Conf. On Fuzzy Systems*, (1992), 1153-1162.
- [11] Luukkonen, T., Tijssen, R.J.W., Persson, O., Sivertsen, G., The Measurement of International Scientific Collaboration, *Scientometrics*, 28 (1993) 15-36.
- [12] Melin, G., Impact of national size on research collaboration - A comparison between Northern European and American universities, *Scientometrics*, 46 (1999) 161-70.
- [13] Melin, G., Persson, O., Studying research collaboration using co-authorships, *Scientometrics*, 36 (1996) 363-77.
- [14] Merriam-Webster Dictionary (Indexed & Unabridged edition). 2002; Available at <http://www.m-w.com/cgi-bin/dictionary?book=Dictionary&va=international&x=0&y=0>.
- [15] Narvaezberthelemot, N., An Index to Measure the International Collaboration of Developing-Countries Based on the Participation of National Institutions - the Case of Latin-America, *Scientometrics*, 34 (1995) 37-44.
- [16] Nauck, D., Krause, R., A neuro-fuzzy approach to obtain interpretable fuzzy systems for function approximation. *IEEE Int. Conf. On Fuzzy Systems*, (1998) 1106-1111.
- [17] Pawlik, K., Rosenzweig, M., *The International Handbook of Psychology*, Sage, London, 2000.
- [18] Uzun, A., Assessing internationality of scholarly journals through foreign authorship patterns: the case of major journals in information science, and scientometrics, *Scientometrics*, 61 (2004) 457-65.
- [19] Wang, L.X., J. M. Mendel, J.M., Generating fuzzy rules from numerical data, with applications, *University of Southern California, Signal and Image Processing Institute, USC-SIPI REPORT #169*, (1991)
- [20] Zadeh, L.A., Fuzzy sets, *Information and Control* 8, (1965) 338-353.
- [21] Zitt, M., Bassecouard, E., Internationalization of Scientific Journals: a Measurement Based on Publication and Citation Scope, *Scientometrics*, 41 (1998) 255-71.