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Application of Scientific Metrics to Evaluate Academic Reputation in Different Research Areas

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***Abstract*—**In this paper, we address the problem of identifying academic reputation of researchers using scientific metrics in different research areas. Due to the characteristics of each area, researchers can present different behaviors. In previous work, we define Rep-Index that makes use of a profile template to individually identify the reputation of researchers. The Rep-Index is comprehensive and adaptive because involves hole trajectory of the researcher built throughout his career and can be used in different areas and in different contexts. Now, we compare our metric (Rep-Index) with the h-index and the g-index through experiments with researchers in the fields of Economics, Dentistry and Computer Science. We analyze the trajectory of 830 Brazilian researchers from the National Council of Technological and Scientific Development (CNPq), which receive grants research productivity. The grants are aimed at productivity researchers that stand out among their peers, enhancing their scientific normative criteria established by CNPq. Of the 830 researchers, 210 are in the area of Economics, 216 of Dentistry e 404 of Computer Science. The experiments show that our metric is strongly correlated with h-index, g-index and CNPq ranking. We also show good results for our hypothesis that our metric can be used to evaluate research in several areas. We apply our metric (Rep-Index) to compare the behavior of researchers in relation to their h-index and g-index through extensive experiments. The experiments showed that our metric is strongly correlated with h-index, g-index and CNPq ranking.

***Keywords*—**Researcher reputation, profile model, scientific metrics.

I. Introduction

CURRENTLY the management of science, technology and innovation go through a qualification process, in order to help researchers in their activities, such as to course corrections in their research, recommendation and guidance for proper application resources. Development agencies, research centers and universities largely feel the need to get information on the scientific and activities developed by its researchers, aiming to support decision making. Thus, development agencies could channel resources to groups with proven expertise in specific research areas, to encourage the development of science and technology and to look for competitive advantages, and academic excellence.

The task of assessing the reputation of a researcher is strongly based on the analysis of your resume or citations to their published papers. It is done when the financial institutions need to analyze the scientific production of researchers to award scholarships and grants, to choose consultants and committee members in approving projects, the classification of journals or simply to evaluate the concept of a program graduate.

The area of scientific metrics have an important role in the academic community may assist in the process of measuring the quality of scientific production and to identify experts in a particular area. The current metrics are based on citations of papers from researchers [1]-[5]. Such metrics do not consider the trajectory of the researcher, not even the scenario in which it is inserted. Even so, they are widely used by the scientific community.

Consider, as an instance, that a fostering agency wants to provide research grants to researchers. How agency can evaluate which researchers are able to receive the resource? What criteria can be used in the review process? How to rank the researchers ensuring that the best have priority to receive the resources?

In previous work, we proposed a method [6] that specifies a profile model researcher (Rep-Model) with data obtained by analysis of his scientific career and ranks at a level of reputation through a metric (Rep-Index). In [7] we present experiments that statistically validate Rep-Model and Rep-Index considering the individual evaluation of researchers. Now, we are interested in to solve the following problem that arises when evaluating research groups rather than individual researchers. How to measure the quality level of research groups? What criteria are interesting to identify beginners groups, intermediate groups and excellence groups? Considering this requirement, in this paper we also use our profile Rep-Model and our metric Rep-Index [6] to identify the reputation of researchers group. This solution may involve several points of view, when researchers are working in different research areas. The approach is premised to be comprehensive and adaptive because it involves several elements of a career researcher and can be used in different areas and in different contexts.

In this paper, we use our metric (Rep-Index) to evaluate the reputation of 830 Brazilian researchers from the National Council for Scientific and Technological Development (CNPq) of three distinct areas: 210 of Economics, 216 of Dentistry and 404 of Computer Science. After, we compared the result of Rep-Index of all researchers with h-index and g-index of each. We show, through extensive experiments, the correlation between the metrics and their potential uses in other research areas.

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The rest of this paper is organized as follows. We first introduce the background and then review related work in Section II. Scientific metrics are described in Section III. Experimental results are presented in Section IV. We conclude the paper in Section V with glimpses at future work.

II. Related Work

The use of metrics to analyze scientific production and to determine the reputation of researchers has been the subject of interest from various research communities from different research areas. Alonso et al. [8] analyzes the h-index and its variants in different scientific areas. The work of Bornmann, Mutz and Daniel [9] discusses proposed variants of h-index and compares them using data from the field of biomedicine. Dodson [10] analyze scientific citations in the context of the h-index and e-index in the areas of Biochemistry and Biophysical. Tol [11] address the h-index and some of its variances to analyze the 100 most productive researchers in the field of economics. Mingers, Macri and Petrovici [12] use the h-index to measure the reputation of journals in the field of business and management. Papavlasopoulos et al. [13] uses a non-linear index to evaluate a journal's scientific impact.

Studies on the reputation of researchers and identifying profiles for reputation analysis are used for many types of applications, such as web-based systems [14], collaborative works [15], social computing [16], recommender systems [17], scientific collaboration networks [18]-[20] and expert finding [21]. Some define key elements to analyze the careers of researchers and others identify reputation in several research areas as in [22]-[24], [18].

In relation to the use of metrics to evaluate scientific productivity scholarship from CNPq, two works are highlighted. In [25], the authors compare the Brazilian researchers of Medicine and perform crossing data of various elements of production. Spilki [26] analyze the profile of researchers in the field of Veterinary Medicine and compares the h-index of each researcher and their ranking in CNPq.

The most popular scientific metrics are h-index [1] and g-index [2]. While h-index measures the impact of a researcher based on the number of publications and their citations, g-index takes into consideration the weight of the citations of the most cited papers and the total number of documents do not limit the index value.

Besides h-index and g-index, some others metrics have also been proposed but are in the initial stage of use. Ar-index [3] is defined as the square root of the sum of the average number of citations per year of papers published. The e-index [5] use the quote discarded by h-index and incorporates them to calculate the new index. Alonso et al. [27] present the Hg-index, a new index to characterize the scientific output of researchers based on the h- and g-indices. Yan, Zhai and Fan [28] present the C-index, a weighted network node centrality measure for collaboration competence. The H l-index [29] improves the h-index based on quality of citing papers. H'-index [30] effectively improves the h-index based on the citation distribution.

Furthermore, other studies also address issues related to improving the h-index and g-index, as well as studies within reputation of researchers with different indices. Among them, we cite the most related: [4], [23], [31]-[38].

Recently a new metric with an important peer evaluated component was developed and published by ResearchGate[1]. In a broad view, this evaluation process involves not only the scientific aspects, such as papers and books, but also by other factors inherent in the activity of a researcher. For example, advisor of graduate students, participation in graduation students' juries, talks presented at conferences, participation in research projects, and others. For instance, the Association for Computer Machinery – ACM[2] recognizes excellence through its eminent series of awards for outstanding technical and professional achievements and contributions in computer science and information technology.

The difference with our work is that our metric (Rep-Index), presented in [6], is comprehensive and adaptive. The comprehensiveness involves the evaluation of reputation of researchers considering the entire scientific trajectory, built along the career. Already adaptability allows the user to use the approach in different areas and in different contexts, adapting the profile model according to specific criteria. Our approach is flexible to the characteristics of each area; it can be used by changing the weights of the elements that meets the needs of the area and the context of use. The approach also enables assessments by categories; it can evaluate the reputation of researchers taking into account only the desired categories.

Our proposal is strongly experiment-based. We collected data from 830 Brazilian researchers who have research productivity scholarship from CNPq (210 are in the area from Economics, 216 from Dentistry and 404 from Computer Science). We crossed the data of the researchers with the h-index and g-index of each researcher (explained in Section IV, Subsection A). Despite the recognized importance of all proposed metrics, we believe that the number of publications and citations must not be considered in isolation to identify the reputation of researchers. It is necessary to analyze other elements of the trajectory of a scientific researcher and the environment in which it is inserted. In this paper, we compare the h-index and the g-index of the 830 researchers with the Rep-Index that is a metric that takes into account the history life of a researcher.

III. Scientific Metrics

This section presents the Rep-Model, the Rep-Index, the h-index and g-index. The Rep-Model aims to specify the profile of researchers and the Rep-Index is a metric for classifying researchers by your reputation. In previous work [6], we specify in details Rep-Model and Rep-Index. Here we present a summary of them in order to clear the main concepts used in experiments. This paper differs from [7] because here we extend far the experiments to deeply show how Rep-Model and Rep-Index can be used together to evaluate researchers of

[1] https://www.researchgate.net
[2] http://www.acm.org

different research areas: in this case, 210 researchers from Economics, 216 from Dentistry and 404 from Computer Science.

The Rep-Model is based on elements that represent the career of a researcher. The chosen elements focus on not only production and citation of papers, but also in the breadth of life science researchers built over their career. In summary, the reputation model represents the behavior of the researcher, identified through a set of elements and their attributes. The Rep-Model is divided into five categories, as follows:

- ID: *Identification* (NM – Name, INST – Institution, ED – Education Degree).
- ADV: *Advisory* (MDA – Master Dissertation Advisor, PTA – Phd Thesis Advisor, PTA – Postdoctoral Advisor).
- EB: *Examining Board* (PEBMD – Participation in Examination Boards Master Dissertation, PEBPT – Participation in Examination Boards Phd Thesis).
- MS: *Membership* (CCC – Conference Committee Coordinator, CCM – Conference Committee Member, EBM – Editorial Board Member, RJ – Reviewer of Journals).
- PROD: *Production* (ASJ – Articles in Scientific Journals, BCP – Book Chapter Published, BP – Books Published, CWPCP – Complete Work Published in Conference Proceedings, HI – H-Index, NC – Network Co-authorship, RP – Research Projects, SOFT – Software).

This separation in categories is needed to better visualize the set of elements of the researcher trajectory.

Rep-Index is a metric for classifying researchers in reputation levels. The levels are identified by a positive integer index that can vary according to the use context. The value of the Rep-Index is calculated by the occurrences of elements of Rep-Model in the life of the researcher. Levels have been proposed to reputation does not exist a large numerical distance between the profiles of the researchers. This becomes clearer identification of reputation. The metric to identify the reputation of researchers is specified in (1). The reputation is defined by a sum of the various elements that make up the Rep-Model. For this, weights are set for the five categories specified in Rep-Model.

$$\text{Rep - Index}_{(R)} = \sum_{i=1}^{c}\left(\sum_{j=1}^{e_i}\frac{(v_j \cdot w_j)}{\max(v_j)}\right) \quad (1)$$

In the following, we present the metric used to calculate the research reputation. First, we present the legend in order to clarify the proposed metrics explanation.

- R : Refers to the researcher who wants to find out the reputation;
- c : Represents the total number of categories.
- i : Represents the range of 1 up to the total number of categories (c).
- e_i : Represents the total elements in each category.
- j : Refers the range of 1 up to the total number of elements (e_i).
- v : Represents the value of the element.
- w_j : Refers to the weight element.
- $\max(v_j)$: Represents the higher value of the element.

Given the maximum value for each identified element, defines the number of intervals for the classification of researchers in the levels of reputation. In our experiments (Section IV) we define five ranges, which resulted in five levels of reputation. To generate the final calculation of the Rep-Index ranges of valid values are shown in (2).

$$\text{Rep - Index}_{(R)} = \begin{cases} 1 \ni \text{Rep - Index}_{(R)} \geq 0 \wedge < 20 \\ 2 \ni \text{Rep - Index}_{(R)} \geq 20 \wedge < 40 \\ 3 \ni \text{Rep - Index}_{(R)} \geq 40 \wedge < 60 \\ 4 \ni \text{Rep - Index}_{(R)} \geq 60 \wedge < 80 \\ 5 \ni \text{Rep - Index}_{(R)} \geq 80 \wedge \leq 100 \end{cases} \quad (2)$$

The Rep-Index for each researcher is obtained by the sum of five categories: ID, MS, ADV, EB and PROD. The result of each category is obtained by multiplying the value of element (v_j) by the weight of the element itself (w_j), divided by the higher value of the element ($\max(v_j)$). It is necessary to identify the higher value of each element, because our model specifies weights for all elements. As our model supports the maximum value of 100 (sum of the weights), a researcher will have a maximum weight on an element limited to equal the weight of that element.

The proposal is adaptive, the model is configurable to represent context and allow the user the flexibility to make adjustments considering its applicability. The Rep-Index uses the Rep-Model to identify the reputation of researchers.

The h-index [1] and g-index [2] are scientific metrics used to identify reputation of researchers. They were proposed with the advent of the web and are considered a new metrics to evaluate the production of researchers and to measure their reputation.

The h-index combines quality and quantity criteria providing a robust single-number metric of an academic's impact. It represents the impact of a researcher based on the number of papers published in n years and the number of citations to each paper. Thus, a research has index h if h of his N_p papers have at least h citations each, and the other ($N_p - h$) papers have no more than h citations each [1].

The g-index improves h-index by giving more weight to highly cited articles. It means that given a set of articles ranked in decreasing order of the citations number, g-index is the (unique) largest number such that the top g articles received (together) at least g^2 citations [2]. The g-index, unlike h-index, takes into consideration the weight of the citations of the most cited papers as well as the total number of documents do not limit the index value, as in the case of h-index.

How h-index and g-index are metrics widely known to quantify the impact of publication researchers, we used them to verify the correlation with CNPq categories.

IV. Experimental Evaluation

In this section we describe the experiments we conducted in order to empirically validate and check the quality of our metric (Rep-Index) to evaluate researchers. Rep-Index is strongly correlated with CNPq scholarship criteria, h-index, and g-index that are metrics widely known and used to quantify scientific productivity on publication record. We first describe the used data domain and baseline, the evaluation metrics, and the methodology adopted. Then, we compare the quality of Rep-Index in comparison with h-index and g-index metrics, and CNPq criteria.

A. Data Domain

We collected data from 830 Brazilian researchers of three research areas: 210 from Economics, 216 from Dentistry and 404 from Computer Science[3]. These researchers receive a grant from the National Council for Scientific and Technological Development (CNPq[4]), an agency of the Ministry of Science, Technology and Innovation (MCT[5]). The main assignments of this grant are to promote scientific and technological research and encourage the formation of Brazilian researchers in different research areas.

Researches receive fellowship according to previous evaluation of their curricula. They are classified into five categories, as follows:

- *Researcher Level 1A*: presents regular scientific production for at least 12 years; has a high number of qualified publications in journals and international conferences; contributes to the development of their area in their country; contributes to the articulation of research groups and formation of new scientists; has national leadership and international recognition, with clear indications of contributions to the national and international community.
- *Researcher Level 1B*: submit regular scientific production for at least 10 years; has qualified publications in journals and international conferences; contributes to the formation of groups of competence, with national and international recognition.
- *Researcher Level 1C*: submit regular scientific production for at least 8 years; has regular production, notably in international journals of good level; has scientific independence and international integration; demonstrates ability to get financial support for research, has advised thesis or dissertations compatible with your doctorate time.
- *Researcher Level 1D*: has submitted regular scientific production for at least 6 years; have international publications in several journals and scientific conferences, with good results after his doctoral research; has advised thesis or dissertations as a member of graduate programs.
- *Researcher Level 2*: has a good international publication; scientific independence with results obtained after his PhD; is involved with advised activities for undergraduate and graduate students.

The main purpose of selecting this domain as comparison is that CNPq has a rigorous criterion to evaluate and choose the best researchers of Brazil. We believe that the use of CNPq categories is a measure of fair and clear comparison. Besides, the following aspects motivate us: (i) the data allow individually analyze researchers; (ii) current analysis of data is performed manually, then, our metric could automate the process; (iii) all the researchers have training in the same area; (iv) possibility to analyze the evolution of the Brazilian scholarship holders; and (v) possibility to cross data to support decision making in future experiments.

The dataset of the 830 researchers have been collected from different sources, all with a high degree of confidence: DBLP[6], Microsoft Academic Search[7], Arnetminer[8] and Lattes Platform[9]. We emphasize that the different sources adopt mechanisms for disambiguation of names, which aided in the process of data extraction. We consider the crawler of data out of this paper scope.

B. Evaluation Metrics

We compare the values of h-index and g-index of 830 researchers with the results obtained when the researcher's resumes were populated in Rep-Model and then processed by Rep-Index. The result of this process was the determination of Rep-Index of researchers.

To analyze the correlation between the indexes, we use the Spearman's rank correlation coefficient, which is a measure of nonparametric statistical dependence between two variables. It assesses how the relationship between two variables can be described. We used the Spearman correlation coefficient due to the heterogeneity of researchers in relation to scientific production. Despite representing a group of excellence in the country, there is much variation in production among researchers. This heterogeneity in the data needed to evaluate the work makes the method is the most appropriate statistical Spearman. The method is also less sensitive to outliers, in which researchers move away from too much at the level of scientific production. Still, Spearman coefficient has been used in several studies involving evaluation or ranking of researchers, as shown in [39]-[43].

We compared the correlation of the classification of scholarship holders of CNPq, levels 1A, 1B, 1C, 1D and 2, with the result obtained by the h-index, the g-index and the Rep-Index of the 830 researchers. The evaluation issue is to show the classification of CNPq is statistically correlated with the outcome of the indexes measured curricula of the researchers.

We used Spearman's rank correlation coefficient due to heterogeneity of researchers. Despite representing all are holders of research grants of CNPq, the production level is high among them. This data heterogeneity makes the best statistical method to evaluate the correlation of rankings is the

[3]Data were collected in June and July 2013.
[4]http://cnpq.br/
[5]http://www.mct.gov.br/
[6]http://dblp.uni-trier.de/
[7]http://academic.research.microsoft.com/
[8]http://arnetminer.org/
[9]http://lattes.cnpq.br/

Spearman. Spearman is also less sensitive to outliers (cases distant curve), which does not occur with the population of our experiments.

C. Experimental Setup

For the experiments, we used the categories and elements in the Rep-Model (Section III). Categories were defined with a weight, where the sum of weights is equal to 100. Similarly, for each element was set a weight, where the sum of these weights is also equal to 100. The weights of the categories and elements have been defined taking into account the CNPq criteria. For instance, the value of papers published in conferences, softwares and research projects. In some areas such elements could be overlooked or undervalued while others may be considered fundamental.

The weights of the elements of the Rep-Model were defined based on the ranking of scholarship productivity holders of CNPq. We adjust the weights of the elements until we get the value of the Rep-Index compatible with the classification of the researcher in the ranking of CNPq. We emphasize that the weights of the elements are adaptive and can be adjusted according to the context and criteria by the user.

The values of the elements were defined by analyzing the curriculum of 830 researchers. For each researcher was analyzed the entire set of model elements, identifying the value of occurrence of each element among all researchers. Having the values of all elements of the researchers, we identified the maximum value of each element. To identify the Higher Value of the Element, we calculated the arithmetic average among the elements of each area. The Higher Value of the Element is necessary to calculate the Rep-Index. The Higher Value of the element is necessary for Rep-Index can generate the reputation levels (1 to 5). He is a parameter for the generation of the five levels.

Table I shows the categories and their weights, the elements and their weights, as well as the average among the higher value of the elements.

TABLE I
CATEGORIES, ELEMENTS, WEIGHTS AND AVERAGE AMONG THE HIGHER VALUE

Category	Category Weight	Element	Element Weight	Higher Value of the Element
ID	15	NM	-	-
		INST	-	-
		ED	15	15
ADV	15	PA	6	13
		PTA	5	59
		MDA	4	116
EB	10	PEBMD	4	159
		PEBPT	6	95
MS	10	CCC	1	23
		CCM	1	57
		EBM	5	15
		RJ	3	54
PROD	50	ASJ	15	237
		BCP	5	84
		BP	7	39
		CWPCP	8	299
		HI	8	31
		NC	3	262
		RP	1	130
		SOFT	1	19
Sum	**100**	**Sum**	**100**	**-**

Given the maximum value for each identified element, we can define the number of intervals for the classification of researchers in the levels of reputation. We define five ranges, resulting in five reputation levels by using the formula previously presented in Section III.

D. Experiment Results

This section presents results related to the experiments to empirically validate and check the quality of Rep-Index proposed to evaluate researcher's trajectories. The experiments are divided into four groups: (i) Rep-Index is compared with CNPq ranking using the average values between the three areas; (ii) Rep-index is compared with CNPq ranking using the values of each area; (iii) calculate the correlation of Rep-Index with the h-index and g-index of all 830 researchers based ranking of CNPq; and (iv) compare the correlation among the weight of Rep-index elements applied in different research areas with the CNPq classification.

1) CNPq Ranking vs Rep-Index (by areas average)

The purpose of this experiment is to verify the equivalence among the result of Rep-Index of researchers in each area with the ranking of each area CNPq. The hypothesis is that the ranking of each area from CNPq is equivalent to the result of Rep-Index of each area.

To perform the experiment, we compared the researchers of every level ranking CNPq for each area, with the result of each level of Rep-Index of researchers in each area. We collect data from all 830 researchers (based on Rep-Model from each area) and generate the Rep-Index of each researcher.

To better understand the results, notice that as the average

value of Rep-Index among researchers can be decimal and Rep-Index is a positive integer (from 1-5), we present the average value in brackets beside the index.

The results can be seen in Figs. 1-3.

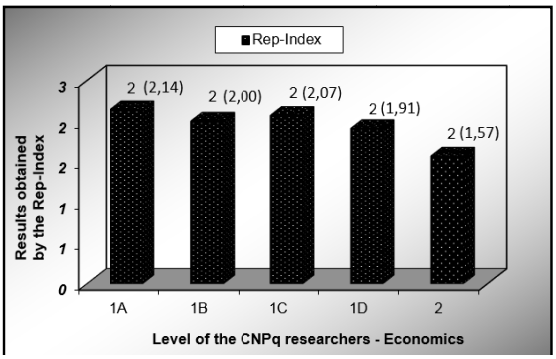

Fig. 1 Rep-Index *vs* CNPq ranking – Economics (areas average)

Fig. 1 shows that the Rep-Index of researchers in Economics followed the ranking of CNPq. The only exception was an inversion between groups 1B and 1C, where the group of researchers 1C showed slightly better performance: Rep-Index 2 (2,07) for the group 1C and Rep-Index 2 (2,00) for the group 1B. This represents an accuracy of 80% when comparing the ranking of CNPq and Rep-Index for the area of Economics.

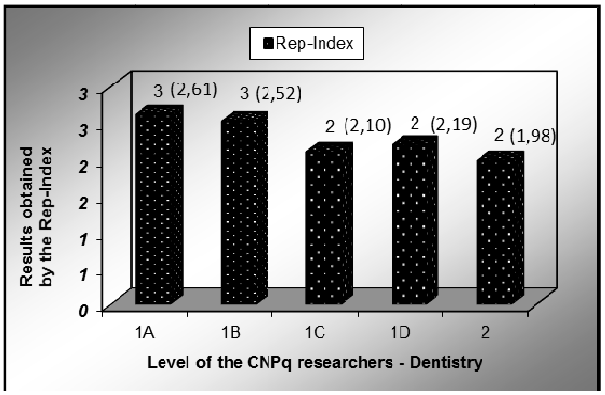

Fig. 2 Rep-Index *vs* CNPq ranking – Dentistry (areas average)

The result of the experiment shown in Fig. 2, the Rep-Index of researchers in Dentistry also followed the ranking of CNPq. Similar to researchers in Economics there was one exception. The exception was an inversion between two groups 1C and 1D, where the group of researchers 1D presented slightly better performance: Rep-Index 2 (2,19) for the group 1D and Rep-Index 2 (2,10) for the group 1C. This also represents an accuracy of 80% when comparing the ranking of CNPq and Rep-Index for the area of Dentistry.

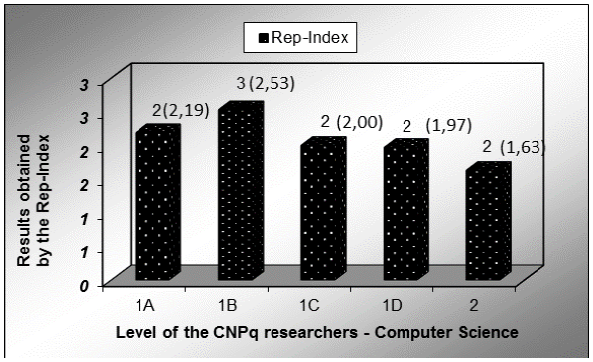

Fig. 3 Rep-Index *vs* CNPq ranking – Computer Science (areas average)

Fig. 3 presents the result of the area of Computer Science. We can observe that the Rep-Index of researchers is equivalent the ranking of CNPq. Similar to researchers in Economics and Dentistry, there was one exception. The exception was an inversion between two groups 1A and 1B, where the group of researchers 1B presented slightly better performance: Rep-Index 2 (2,53) for the group 1B and Rep-Index 2 (2,19) for the group 1A. This also represents an accuracy of 80% when comparing the ranking of CNPq and Rep-Index for the area of Computer Science.

2) CNPq Ranking vs Rep-Index (by values of each area)

The purpose of this experiment is to verify the equivalence between the result of Rep-Index and CNPq ranking applied in several areas (Economics, Dentistry and Computer Science). The hypothesis is that the Rep-index is equivalent with the ranking of CNPq in each area.

To perform the experiment, we collected data from 830 researchers using the Rep-Model of each area individually, in order to generate the Rep-Index of each researcher.

The results of experiment can be seen in Figs. 4-6.

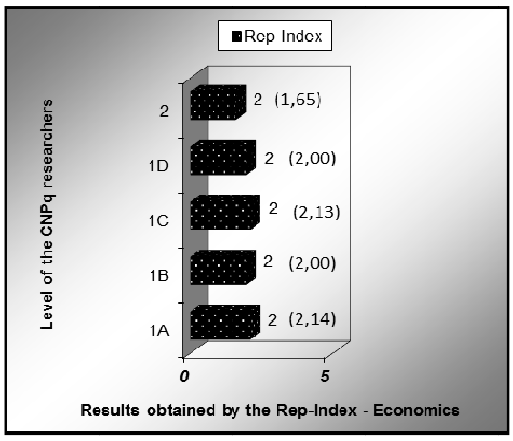

Fig. 4 Rep-Index *vs* CNPq ranking – Economics (individual area)

Fig. 4 shows that the Rep-Index of researchers in Economics followed the ranking of CNPq, considering the average of own area of Economics. The only exception was an

inversion between two groups: 1B and 1C, where the group of researchers 1C showed slightly better performance: Rep-Index 2 (2,13) for the group 1C and Rep-Index 2 (2,00) for the group 1B. It represents an accuracy of 80% when comparing the ranking of CNPq and Rep-Index for the area of Economics. The result was the same as that presented in Section IV, Subsection D (1).

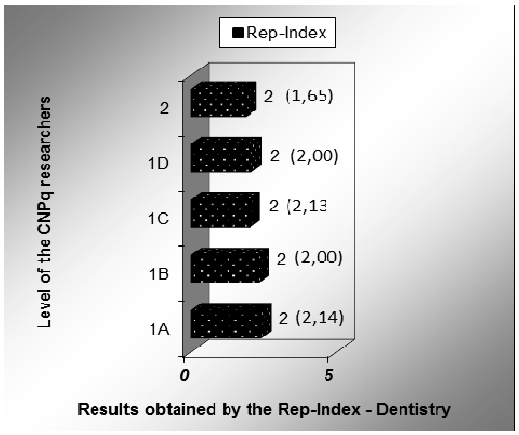

Fig. 5 Rep-Index *vs* CNPq ranking – Dentistry (individual area)

The result of the experiment shown in Fig. 5, the Rep-Index of researchers in Dentistry also followed the ranking of CNPq. Similar to researchers in Economics, there was one exception. The exception was an inversion between two groups 1B and 1C, where the group of researchers 1C presented slightly better performance: Rep-Index 2 (2,13) for the group 1C and Rep-Index 2 (2,00) for the group 1B. It also represents an accuracy of 80% when comparing the ranking of CNPq and Rep-Index for the area of Dentistry. The result was the same as that presented in Section IV, Subsection D (1).

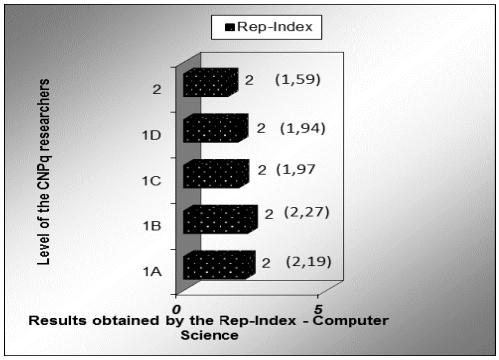

Fig. 6 Rep-Index *vs* CNPq ranking - Computer Science (individual area)

Fig. 6 presents the result of the area of Computer Science. Observe that the Rep-Index of researchers followed the ranking of CNPq.

Similar to researchers in Economics and Dentistry, there was one exception. The exception was an inversion between two groups 1A and 1B, where the group of researchers 1B presented slightly better performance: Rep-Index 2 (2,27) for the group 1B and Rep-Index 2 (2,19) for the group 1A.

It also represents an accuracy of 80% when comparing the ranking of CNPq and Rep-Index for the area of Computer Science. The result was the same as that presented in Section IV, Subsection D (1).

3) Spearman's Correlation among Indices

The objective of this experiment is to calculate the correlation of Rep-Index with the h-index and g-index of all 830 researchers based ranking of CNPq. The expected result is that there is strong correlation between the three indices and the ranking of the CNPq.

To perform the experiment, we use the Spearman's rank correlation coefficient to correlate the three indices. We analyze the researchers by area and within the levels of CNPq. For the definition of Rep-Index, we used the Rep-Model with the result of each level of Rep-Index of researchers in each area.

We collect the h-index and g-index of all 830 researchers and generate the Spearman correlation for each level of the CNPq with the Rep-Index of 830 researchers.

The results of experiment are presented in Figs. 7-9.

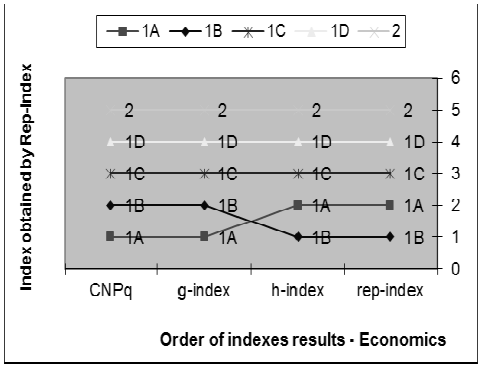

Fig. 7 Spearman of the scholarship holders of CNPq with indexes G, H and Rep – Economics

Fig. 7 shows that the g-index of researchers from Economics followed the ranking of CNPq (Spearman's rank correlation coefficient = 1,0). The h-index and g-index had among researchers Level 1A and 1B, where those related to the level 1B obtained slightly better results. Even so, the Spearman's rank correlation coefficient of these two indices showed a strong correlation with the result of 0.9.

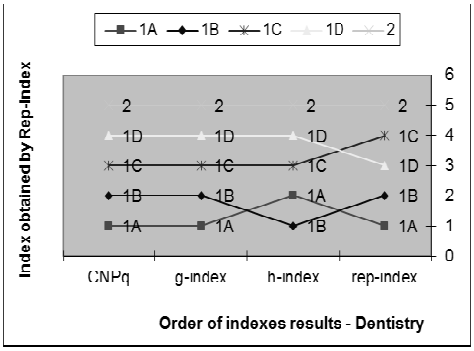

Fig. 8 Spearman of the scholarship holders of CNPq with indexes G, H and Rep – Dentistry

The result of the experiment shown in Fig. 8 presents that the g-index of researchers from Dentistry followed the ranking of CNPq (Spearman's rank correlation coefficient = 1,0).

Regarding the h-index and the Rep-Index, there were some variations. Researcher's levels 1A and 1B inverted position relative to the h-index. Even so, the calculated Spearman's rank correlation coefficient was 0,9, which represents a strong correlation.

For the Rep-Index, change occurred among researcher's levels 1C and 1D. Despite the strong correlation found (Spearman = 0,9), researchers at the 1D level showed better performance than the level 1C.

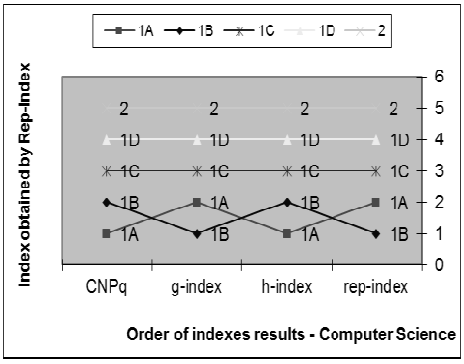

Fig. 9 Spearman of the scholarship holders of CNPq with indexes G, H and Rep - Computer Science

Fig. 9 shows the results of the indices of the area of Computer Science. With respect to the g-index, there is no change and Spearman correlation was 1.0.

The h-index of researcher's levels 1A and 1B reversed, i.e., the researchers showed the level 1B h-index higher. Nevertheless, the Spearman was 0.9, representing a strong correlation. As for the Rep-Index, the Spearman result was 0,8. In this case, there was also a reversal of position among researcher's levels 1A and 1B, where the level 1B showed slightly higher performance.

4) Spearman's Correlation of Rep-Model Elements

This experiment aims to compare if the element weights of Rep-Model in each area are correlated with CNPq classification. We believe that the result must be a strong correlation between the Rep-Model elements and CNPq classification.

To perform this experiment, we use the Spearman's rank correlation coefficient. We collected 830 data researchers using as base all elements of Rep-Model. After, we process these data to calculate the Rep-Index from 830 researchers.

The results of experiment are presented in Figs. 10-12.

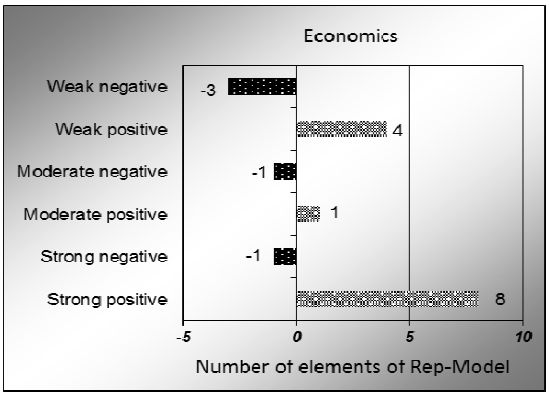

Fig. 10 Correlation of the elements from Rep-Model – Economics

Fig. 10 shows the results of the Spearman's rank correlation coefficient the area of Economics. We can see that eight elements of Rep-Model showed strong correlation among researchers in Economics. Four elements presented correlation weakly positive and three weakly negative. Regarding the strong negative results, moderate positive and moderate negative, was identified only one element each.

Below we present the elements and their correlation:

- *Strong positive*: Master Dissertation Advisor, Conference Committee Coordinator, Conference Committee Member, Articles in Scientific Journals, Book Chapter Published, Books Published, H-Index, Network Co-authorship;
- *Strong negative*: Reviewer of Journals.
- *Moderate positive*: Editorial Board Member.
- *Moderate negative*: Research Projects.
- *Weak positive*: Education Degree, Postdoctoral Advisor, Phd Thesis Advisor and Software.
- *Weak negative*: Participation in Examination Boards Master Dissertation, Participation in Examination Boards Phd Thesis and Complete Work Published in Conference Proceedings.

Fig. 11 shows the results of the Spearman's rank correlation coefficient the area of Dentistry.

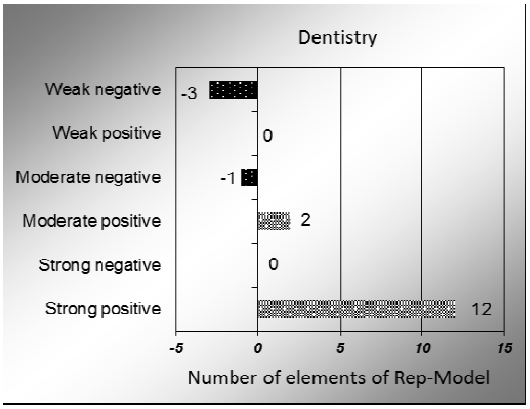

Fig. 11 Correlation of the elements from Rep-Model – Dentistry

We can see in Fig. 11 that twelve elements of Rep-Model showed strong correlation among researchers in Dentistry, two presented correlation moderate and three weakly negative. Regarding the strong negative results, weak positive and moderate negative, was identified, respectively, with zero, zero and one.

Below we present the elements and their correlation:

- *Strong positive*: Postdoctoral Advisor, Phd Thesis Advisor, Master Dissertation Advisor, Participation in Examination Boards Master Dissertation, Participation in Examination Boards Phd Thesis, Conference Committee Coordinator, Conference Committee Member, Articles in Scientific Journals, Book Chapter Published, Books Published, H-Index and Network Co-authorship;
- *Strong negative*: Neither.
- *Moderate positive*: Editorial Board Member and Complete Work Published in Conference Proceedings.
- *Moderate negative*: Software.
- *Weak positive*: Neither.
- *Weak negative*: Education Degree, Reviewer of Journals and Research Projects.

Fig. 12 shows the results of the Spearman's rank correlation coefficient the area of Computer Science.

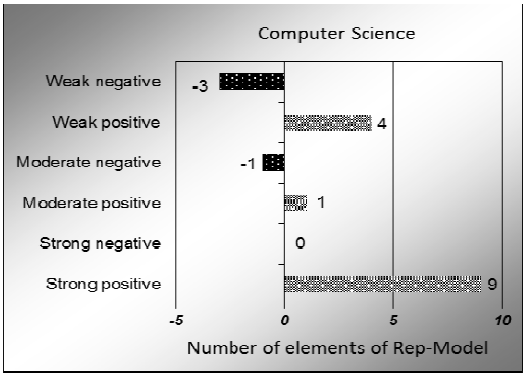

Fig. 12 Correlation of the elements from Rep-Model – Computer Science

We can see that nine elements of Rep-Model showed strong correlation among researchers in Computer Science, four presented correlation weakly positive while three weakly negative. Regarding the strong negative results, moderate positive and moderate negative, we identified, respectively, with zero, one and one.

Below we present the elements and their correlation:

- *Strong positive*: Postdoctoral Advisor, Phd Thesis Advisor, Master Dissertation Advisor, Editorial Board Member, Articles in Scientific Journals, Book Chapter Published, Books Published, H-Index and Network Co-authorship;
- *Strong negative*: Neither.
- *Moderate positive*: Education Degree.
- *Moderate negative*: Research Projects.
- *Weak positive*: Participation in Examination Boards Phd Thesis, Conference Committee Coordinator, Reviewer of Journals and Complete Work Published in Conference Proceedings.
- *Weak negative*: Participation in Examination Boards Master Dissertation, Conference Committee Member and Software.

5) Result Analysis

After accomplish all the experiments, analyzed the results in order to identify patterns, trends and behavior.

Regarding the behavior of researchers in the fields of Economics, Dentistry and Computer Science, taking into account the classification of the CNPq, the results confirmed our hypothesis. Even if there are some differences between the areas, the accuracy was 80%, which states that the criteria CNPq are relevant and consistent. The experiments were performed by the average productivity among the three areas, as well as individually for each area. In both the results were correlated.

We identified that the Rep-Index of 830 researchers in Economics, Dentistry and Computer Science has a strong correlation with the h-index and the g-index, because the Spearman's rank correlation coefficient between the three indices approached 1,0. This validates the feasibility of using Rep-Index in different research areas and in different contexts, because their approach is comprehensive and adaptive.

We also analyzed the correlation of the elements of Rep-Model within the areas of Economics, Dentistry and Computer Science. Of eighteen (18) elements of Rep-Model, we identified a strong correlation with six (6) of them of the three areas used. They are, Master Dissertation Advisor Articles in Scientific Journals, Published Book Chapter, Published Books, H-Index and Network Co-authorship. Other elements of Rep-Model also stood out. Four (4) of them showed a strong correlation between two of the three areas used. They are, Postdoctoral Advisor, Phd Thesis Advisor, Conference Coordinator Committee and Conference Committee Member.

Some elements of Rep-Model showed weak correlation or negative correlation. This is the case of elements Degree Education, Participation in Examination Boards Master Dissertation, Participation in Examination Boards Phd Thesis, Reviewer of Journals, Complete Work Published in Conference Proceedings and Software. The other elements,

Research Projects and Editorial Board Member showed moderate correlation between the three areas studied.

Fig. 13 shows the correlation between the percentages of Rep-Model elements of the average of the areas.

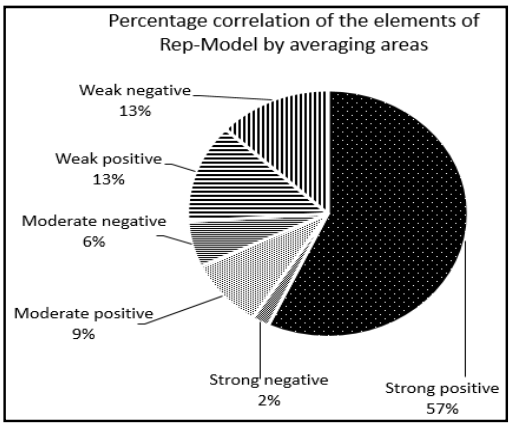

Fig. 13 Percentage correlation of the elements of Rep-Model

We can observe in Fig. 13 that the strong positive correlation reached a percentage of 57% on average between the three involved areas (Economics, Dentistry and Computer Science). Moreover, moderate positive correlation was 9%. If we add the percentage of the two correlations, we will reach a value of 66%. This result shows that the Rep-Model elements can be used in different research areas and different contexts.

Despite the large amount of data involved in the experiments, the diversity of the areas chosen, the characteristics of each area, as well as the heterogeneity of the data, the result of 66% correlation strongly positive and moderate positive, was very satisfactory.

V. Concluding Remarks and Future Work

In this paper, we address the problem of identifying academic reputation of researchers using scientific metrics. In previous work, we proposed a new way of evaluate researchers. We have specified Rep-Index that is a metric that makes use of a profile (Rep-Model) template to individually identify the reputation of researchers. Now, we compare our metric (Rep-Index) with the h-index and the g-index through experiments with researchers in the fields of Economics, Dentistry and Computer Science. We have shown that our metric can be applied to evaluate researchers in several areas.

In this paper, we performed an exhaustive experiment set using metrics for comparison our proposed metric with h-index and g-index, which are widely used in the scientific community. We also measured the correlation from our metric with CNPq classification, whose criteria are widely used to evaluate researchers and award research grants in Brazil. We show good results in all areas analyzed. We believe that despite Recognized the Importance of h-index and g-index, the number of publications and citations must not be considered in isolation to identify the reputation of researchers. It is Necessary to analyze other elements of the trajectory of a scientific researcher and the environment in which it is inserted.

In future work, we intend to evaluate the Rep-Index of 830 researchers, but this time using only the elements of Rep-Model that showed strong correlation and moderate correlation. Our hypothesis is that using only these elements we will have different (and better) behaviors between levels of CNPq researchers.

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