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Detecting rising stars in dynamic collaborative networks

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ABSTRACT

In today's complex academic environment the process of performance evaluation of scholars is becoming increasingly difficult. Evaluation committees often need to search in several repositories in order to deliver their evaluation summary report for an individual. However, it is extremely difficult to infer performance indicators that pertain to the evolution and the dynamics of a scholar. In this paper we propose a novel computational methodology based on unsupervised machine learning that can act as an important tool at the hands of evaluation committees of individual scholars. The suggested methodology compiles a list of several key performance indicators (features) for each scholar and monitors them over time. All these indicators are used in a clustering framework which groups the scholars into categories by automatically discovering the optimal number of clusters using clustering validity metrics. A profile of each scholar can then be inferred through the labeling of the clusters with the used performance indicators. These labels can ultimately act as the main profile characteristics of the individuals that belong to that cluster. Our empirical analysis gives emphasis on the “rising stars” who demonstrate the biggest improvement over time across all of the key performance indicators (KPIs), and can also be employed for the profiling of scholar groups.

1. Introduction

Evaluation of faculties and research scholars in the modern academic world is becoming increasingly difficult. The main problems pertain to the different objectives that each faculty or department sets, but also to the constantly changing academic market. More precisely, there is a shift from the full-time, tenure-eligible faculty members that used to be the case in the past, to increasing numbers of part-time faculty members, non-tenure-track faculty members, and even online course instructors in colleges and universities around the globe. In addition, there is lack of widely accepted guidelines, but instead there is a plethora of best practices, often released by each faculty individually, on how the evaluation should take place (Buller, 2013).

As a result, the evaluation committees often need to provide evaluation summary reports of individuals that are aligned with the faculty's scope and objectives, and need to do so without having the ability or the time to meet the candidate in person. For this purpose, there is a large need of automated tools that can provide an analysis of the scholars' profiles based on a wide range of key performance indicators (KPIs) that may cover the majority of the faculty's needs or goals.

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There is certainly a large number of KPIs that may be considered for the evaluation of academics and faculties. Teaching and research performance, ability to raise research funds, as well as patents awarded or pending are only few of the aspects that may be considered for such an evaluation. In this work we are focusing on the evaluation of individual scholars from the perspective of their research activities performance. We argue that the scientific performance of individuals should take into consideration apart from bibliometric indicators such as the h-index (Hirsch, 2005) and journal impact factors, the social aspects of the researcher's contribution as well as its dynamics. The rationale behind this argument stems on the one hand from several past observations around the inconsistency of h-index (Waltman & Eck, 2012) and impact factor (Seglen, 1997) while, on the other hand, from the limitations that a single number evaluation model suffer from, like narrowing the margins of alternative interpretations and consequently, failing to highlight the advantages, disadvantages and future potential of a scholar. Such a view would also aid the evaluation committees to document in detail the rationale behind their decision and align it easier with the faculty's goals.

In order to address the aforementioned requirements, we present a computational method to analyze the profiles of individual scholars based on a number of performance indicators covering both scientific performance and social/collaboration related features, as well as their evolution over time. To measure an author's productivity and impact of his work we employ alternations of metrics such as the volume of publications and citations each work receives, emphasizing on their ephemeral character to distinguish between truly seminal works and temporal successes. Furthermore, to measure an author's sociability, which accounts for the number of co authorships he or she forms and their impact on his or her career, collaboration networks are exploited, i.e., co-authorship graphs, that are created from bibliographic data and analyzed using traditional graph mining (Cook & Holder, 2006) and Power Graph Analysis (Royer, Reimann, Andreopoulos, & Schroeder, 2008). We then proceed to measure the changes of each such indicator across consecutive time periods in order to capture the scholar's dynamics. As a final step, we cluster the scholars' profiles in each period using all of these indicators as features and perform a feature analysis to characterize the clusters and an evaluation using the clusters future values.

The evaluation of academic performance has several ethical implications, which have been extensively discussed in the related literature. For example, Sir Philip Campbell, the Editor-in-Chief of Nature journal, stated that the most effective and fair analysis of a person's contribution derives from a direct assessment of individual papers, and not of the venues they were published (Campbell, 2008). This reduced the importance of an impact factor and increased the significance of individual (per publication) citations (Cronin, 1984). Similarly, the widely known *h-index* received criticism since in some cases it may provide misleading information about a scientist's output or can be biased in various ways, such as using self-citations, publishing in different research domains, open access, the cumulative advantage of more senior researchers, etc. (Allison, Long, & Krauze, 1982; Antelman, 2004; Batista, Campiteli, & Kinouchi, 2006; Harzing & van der Wal, 2008; Hirsch, 2007; Wendl, 2007). The use of large bibliographic and citation databases (e.g. Scopus, Google Scholar, etc.) that provide the exact number of citations per publication solved the venue impact bias and also the cumulative bias of old papers, but there are still issues to be solved, such as the quantification of each author's contribution in a publication. A comprehensive survey on the pitfalls of research evaluation and a plan for objectivity in evaluation metrics is presented by Retzer and Jurasinski (2009). Another aspect that is also under extensive examination is how to evaluate the actual quality of a scientific work, which is an a rather multifaceted and complicated task (Andersen, 2013; Frey & Rost, 2010) that comprises more than simple publication and citation count (Ochsner, Hug, & Daniel, 2014). In this article, we propose a set of indexes that can be used to evaluate multiple facets of an author's research potential, we penalize the impact of a work as time passes and focus on the changes of these indexes across time in order to remove the cumulative bias and instead of ranking authors or classifying authors to good or bad ones, we cluster authors of similar potential into groups. This grouping can be more useful in a researcher selection process, since it can restrict the number of candidates to a smaller group of individuals with strong potential, leaving space for a selection process that takes into account all the aspects of each candidate without staying only on raw numbers and indexes.

We tilt our analysis over the cases of rising stars due to their significance and challenging nature. Li, Foo, Tew, and Ng (2009) describe rising stars are those who currently have relatively weak profiles but may eventually emerge as prominent researchers. The difficulty in identifying rising stars is that it is essentially a prediction task that spans across several years, rather than an instantaneous classification task. More specifically, it is necessary to collect data from when the author is still relatively inconspicuous and for a period of time in order to claim at an early stage that he or she will become a great scientist in the future. Thus, one has to look in specific details that reflect the potential of this author, rather than traditional metrics of author assessment. Furthermore, it is important to follow the author publication and citation record over time in order to validate that the prediction was correct. In our previous work (Tsatsaronis et al., 2011), attempting to model the "group leaders" profiles, we also defined rising stars as the authors who show high increase in the amount and impact of their published work over time. Daud, Abbasi, and Muhammad (2013) define rising stars as the authors which may become prominent contributors in the future, though are currently having a low research profile.

The novelty and the main contribution of the current work lies in the fact that for the first time to the best of our knowledge, quantity, impact and collaboration related features are combined together and monitored over time in order to create profiles of scholars and to highlight their strengths and weaknesses. Based on a set of time evolving features, a clustering algorithm and several cluster validity measures, authors are grouped into subsets of relevant performance. The clusters are consequently labeled based on their most representative features; for each cluster the features with the highest values across clusters are used. An additional contribution of this work is the methodology we use in the analysis of clusters,