



Regular article

Topological metrics in academic genealogy graphs

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ABSTRACT

Academic genealogy aims to structure and analyze the mentoring relationships between advisor and advisee. The representation of this structure results in academic genealogy graphs. For the analysis and characterization of these graphs, we present a set of metrics and their corresponding mirror metrics that capture the characteristics of its topological structure and represent them as quantitative attributes. The metrics of fecundity, fertility, descendants, cousins, generations, and relationships consider the descendants of the academics represented in the graph. The mirror metric of these topological metrics considers the ascendancy of academics. Individually, the metrics have strong semantic intuition and define characteristics regarding the performance in the mentoring of an academic. Together, the metrics are useful for the identification, characterization, and classification of communities and their members. The genealogical data available through the platforms of the Mathematics Genealogy Project and the Academic Family Tree were used as case studies. Two hundred thirteen thousand and 675,000 academic records were obtained for each project. We analyze the capacity of characterization of the metrics using the structuring of a similarity graph and through the distribution of the nodes in principal components. We observed that the set of metrics is capable of capturing the configuration pattern existing in genealogy graphs independently of its scale.

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1. Introduction

Research that has scientific knowledge and its development as the object of study considers the characterization of academics and researchers through the analysis of their publications. Thus, it is natural to use bibliometric indicators for this purpose (Agarwal et al., 2016; Todeschini & Baccini, 2016). On the other hand, there is a growing interest in the way these actors relate to each other and transmit scientific knowledge through these relationships. Thus, relationships of academic mentoring have been considered as a complement to the analysis of publications to obtain better results in the context of scientific production.

The activity of academic mentoring promotes the evolution of the advisee, of the institution, of the science, and of the society. Currently, we observe different initiatives to documenting, analyzing and classifying structures of academic genealogy (Didegah & Thelwall, 2013; Gargiulo, Caen, Lambiotte, & Carletti, 2016; Malmgren, Ottino, & Amaral, 2010). Analyzing

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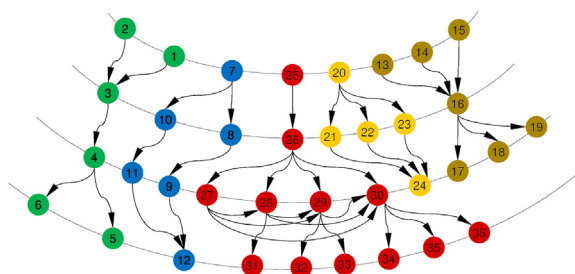


Fig. 1. Example of a general genealogical graph. Each vertex represents an academic and are positioned in hierarchical order (generations) defined by the direction of the edges. The same color indicates a connected component or academic family. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of the article.)

these relationships in the form of a genealogical structure allows a deeper understanding of the scientific community, and of the individual through their relationships.

Academic genealogy (AG) is defined as a quantitative study of the intellectual heritage perpetuated through academic mentoring relationships between researchers (advisors/supervisors) and their students (advisee) (Sugimoto, 2014). The AG may be a viable way to classify scholars based on their contributions to training human resources and to identify groups with similar performances. The motivation underlying the use of AG as a form of evaluation is the belief that the most efficient way for a scientist to work beyond his or her time is to provide to the next generation of academics mentored by them scientific ideas that may influence youngsters to continue their works, contributions and visions.

Analysis considering AG involves the following steps: (i) genealogical data mining (Wang et al., 2010), (ii) genealogical graph structuring (Vicknair et al., 2010), (iii) graph characterization (David & Hayden, 2012), and (iv) the discovery of knowledge in these structures (Sugimoto, Ni, Russell, & Bychowski, 2011). The characterization of AG structures can be performed using metrics that reflect characteristics referring to the topology of these structures and are useful for the classification of academics (Rossi, Freire, & Mena-Chalco, 2017).

The purpose of this paper is to describe a set of metrics that are useful for the characterization of academic genealogy graphs and that have the following characteristics: (i) are simple to obtain and interpret, (ii) individually provide information about the topological structure of the graph and/or that are semantically strong, (iii) globally foster the identification of academic communities with apparent characteristics and (iv) are independent of the scale of the data considered. In the context of bibliometric analysis, it is possible to identify a wide range of publications that describe metrics for their characterization, such as co-authorship networks. However, to the documentation of AG reviews is limited. The graphs of AG have particular characteristics regarding structure and semantics, so it is essential to develop specific tools for the exploration of these structures.

We consider the use of a set of 12 topological metrics. The first six metrics are based on the descent of a vertex of interest. Next, we introduce new other metrics that are mirror symmetries of the first group. They are based on the ascendancy of a vertex of interest. The latter is useful for differentiating vertices that have no descendants. As case studies, we use an example graph (artificial) that contributes to the definition of the metrics and two sets of real genealogical data. The datasets in question are the Mathematics Genealogy Project and the Academic Family Tree project. The characterization of these datasets is not part of the scope of this paper. The analysis presented shows the ability of the metrics to characterize genealogy graphs. Thus, the focus is on the proposed method and not on the characterization of data.

2. Materials and methods

The analyses performed for this paper are based on genealogy graphs (directed graph). A directed graph \vec{G} is a pair of (V, E) , where V is a finite set of vertices and E , edges, is a binary relation in V . Vertices (V) represent individuals (academics) and the directed edges (E) represent the mentoring relationships.

The academic lineage is a path in the genealogy graph that connects with the forbears or descendants. Formally, a path with length k from a vertex source to a vertex destination ($u \rightsquigarrow u'$) in a directed graph (\vec{G}) is a sequence of vertices $(v_0, v_1, v_2, \dots, v_k)$ such that $u = v_0$, $u' = v_k$ and $(v_{i-1}, v_i) \in E$ for $i = 1, 2, 3, \dots, k$.

Fig. 1 shows a general genealogy graph where the vertices (academics) are labeled with numbers, and the edges (relationships) connect the vertices. The direction of the edges indicates the origin and the destination of mentoring and represent the advisor and the advisee, respectively. The position of the vertex in the graph indicates the generation to which it belongs (hierarchical order defined by the direction of the edges). The vertices that have the same color form an academic family (connected component).

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