Noname manuscript No.
(will be inserted by the editor)

A Fast Algorithm for Node-Centric Betweenness Centrality

First Author · Second Author

Received: date / Accepted: date

Abstract Insert your abstract here. Include keywords, PACS and mathematical subject classification numbers as needed.

Keywords First keyword · Second keyword · More

1 Introduction

A social network consists of a set of actors, like persons or organizations, and one or more types of relations between them. Betweenness is a popular measure of centrality investigated in the context of social network analysis. Betweenness of an actor indicates the extent to which the actor is between all other actors within a given social network, and it expresses the importance and influence of the actor in the social network (Freeman 1979).

Calculating the betweenness of each node, however, requires finding all of the shortest paths between every pair of nodes in the given network. Since carrying out this task in a large network will incur prohibitively expensive computational costs, a large amount of research for estimating betweenness have been carried out. Although the estimating techniques efficiently estimate the betweenness measure with a low error margin, the exact betweenness calculation of only one node is still In these techniques (Daly and Haahr 2009; Marsden 2002; Everett and Borgatti 2005; Nanda and Kotz 2008; Pantazopoulos et al. 2013), each node identifies its *ego network*, a logical network consisting of that node, its 1-hop neighbors, and all links between these nodes. Then, each

F. Author
first address
Tel.: +123-45-678910
Fax: +123-45-678910
E-mail: fauthor@example.com

S. Author
second address

node calculates, as an estimate of its betweenness in the entire network, its betweenness only in its ego network, thereby saving both network and computational resources.

2 Problem Definition and Related Work

In this paper, we consider a graph $G(V, E)$ where V is a set of vertices and E is a set of undirected and unweighted edges representing social links between vertices[1]. Given a graph $G(V, E)$, the betweenness $B(v)$ of a vertex v is defined as:

$$B(v) = \frac{\sum_{s \neq v \neq t \in V} \frac{\sigma_{st}(v)}{\sigma_{st}}}{(|V| - 1)(|V| - 2)} \quad (1)$$

where σ_{st} is the number of shortest paths from vertex s to vertex t and $\sigma_{st}(v)$ is the number of those shortest paths that pass through vertex v. In the above definition, the denominator represents the total number of pairs of all vertices except v, and normalizes $B(v)$ to a value between 0 and 1. Given an undirected graph, $\sigma_{st} = \sigma_{ts}$ and $\sigma_{st}(v) = \sigma_{ts}(v)$ for all vertices s, t, and v, so that it is sufficient to find either σ_{st} or σ_{ts} and either $\sigma_{st}(v)$ or $\sigma_{ts}(v)$.

The fastest algorithm for exactly computing the betweenness of every vertex in a given graph is developed by Brandes (2001). Given an unweighted graph, the Brandes algorithm performs a breadth first search to compute the number of shortest paths from any pair of two vertices. It then derives the betweenness of each vertex by aggregating the previously computed count values backwards along the edges. Given an unweighted graph $G(V, E)$, this Brandes algorithm takes $O(|V||E|)$ time.

Since the exact calculation of the betweenness even for a single vertex involves the computation of the shortest path between any pair of vertexes, a feasible solution is to estimate the betweenness values. Vertex sampling consists in selecting a set of nodes in a graph (Eppstein and Wang 2001; Chehreghani 2014; Agarwal et al. 2015). The selected nodes are called pivot nodes. The process of sampling the nodes can be fully random or based on a heuristic. Usually, for the purpose of betweenness estimation, the computation of the shortest paths is only executed over the sampled nodes, and the betweenness values are estimated for every vertex in a graph or just for a set of top-class vertexes.

Text with citations **?** and **?**.

2.1 Subsection title

as required. Don't forget to give each section and subsection a unique label (see Sect. 2).

[1] We use the term *actors* and *social links* to refer to individuals, groups or organizations and their relationships in a social network. On the other hand, the graph representing a social network consists of *vertices* and *edges* representing actors and social links, respectively.

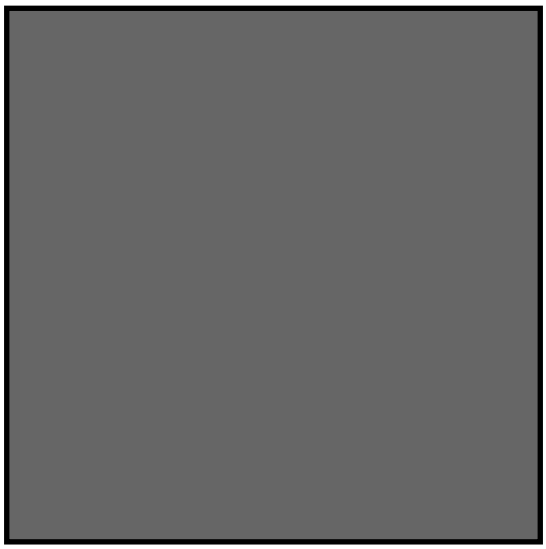

Fig. 1 Please write your figure caption here

Table 1 Please write your table caption here

first	second	third
number	number	number
number	number	number

Paragraph headings Use paragraph headings as needed.

$$a^2 + b^2 = c^2 \tag{2}$$

References

Agarwal M, Singh RR, Chaudhary S, Iyengar SRS (2015) An efficient estimation of a node's betweenness. In: Mangioni G, Simini F, Uzzo SM, Wang D (eds) Complex Networks VI, Springer International Publishing, Cham, pp 111–121

Brandes U (2001) A faster algorithm for betweenness centrality. Journal of Mathematical Sociology 25:163–177

Chehreghani MH (2014) An Efficient Algorithm for Approximate Betweenness Centrality Computation. The Computer Journal 57(9):1371–1382

Daly EM, Haahr M (2009) Social Network Analysis for Information Flow in Disconnected Delay-Tolerant MANETs. IEEE Trans Mobile Comput 8(5):606–621

Eppstein D, Wang J (2001) Fast approximation of centrality. In: Proceedings of the Twelfth Annual ACM-SIAM Symposium on Discrete Algorithms, Society for Industrial and Applied Mathematics, Philadelphia, PA, USA, SODA '01, pp 228–229, URL http://dl.acm.org/citation.cfm?id=365411.365449

Everett M, Borgatti SP (2005) Ego Network Betweenness. Social Networks 27(1):31–38

Freeman LC (1979) Centrality in Social Networks: Conceptual Clarification. Social Networks 1:215–239

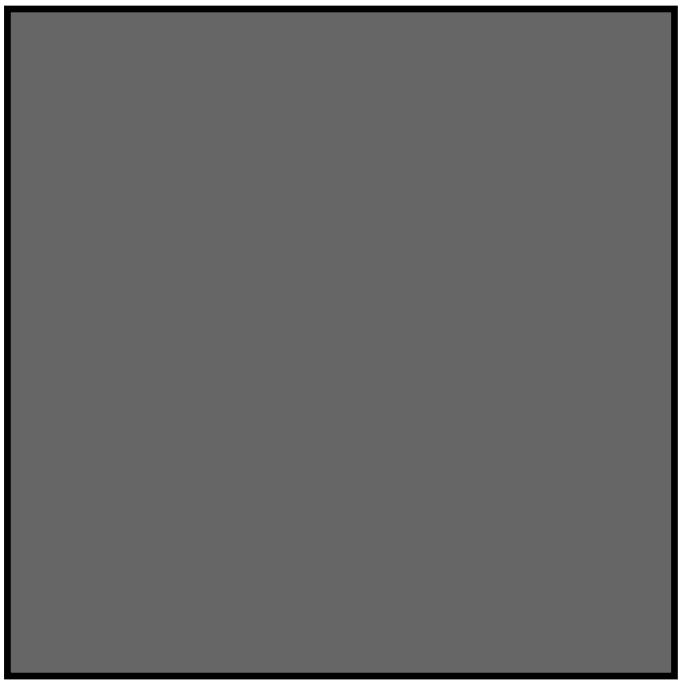

Fig. 2 Please write your figure caption here

Marsden PV (2002) Egocentric and Sociocentric Measures of Network Centrality. In: Social Networks, vol 24, pp 407–422

Nanda S, Kotz D (2008) Localized Bridging Centrality for Distributed Network Analysis. In: Proc. of IEEE ICCN

Pantazopoulos P, Karaliopoulos M, Stavrakakis I (2013) On the Local Approximations of Node Centrality in Internet Router-level Topologies. In: 7th Int'l Workshop on Self-Organizing Systems (IFIP IWSOS'13)