The co-authorship network and scientific impact of László Lovász

Béla Barabás[1], Ottilia Fülöp[2], and Roland Molontay[1]

[1] Dept. of Stochastics, Budapest University of Technology and Economics, Hungary
[2] Dept. of Diff. Eq., Budapest University of Technology and Economics, Hungary
belab@math.bme.hu, otti@math.bme.hu, molontay@math.bme.hu

This paper is dedicated to László Lovász at the occasion of his 70^{th} birthday.

Abstract. Research collaboration is a central mechanism that combines distributed knowledge and expertise into common new original ideas. Considering the lists of publications of László Lovász from the Hungarian bibliographic database MTMT, we illustrate and analyze the collaboration network determined by all co-authors of Lovász, considering only their joint works with Lovász.

In the second part we construct and analyze the co-authorship network determined by the collaborating authors of all scientific documents that have referred to Lovász according to the Web of Science citation service. We study the scientific influence of László Lovász as seen through this collaboration network. Here we provide some statistical features of these publications, as well as the characteristics of the co-authorship network using standard social network analysis techniques.

1 Introduction

The representation and analysis of social networks showing scientific interactions between researchers have gained a lot of interest in the last decades. Co-authorship networks have been studied from numerous angles, e.g. the collaboration network of a research community that cites a certain important paper or the network determined by the authors who published in a specific journal, or regarding a particular country [7, 8, 12, 17, 18].

In this paper, we present two co-authorship networks related to László Lovász, a Hungarian mathematician who strongly influenced the fast evolution of combinatorial optimization, graph theory, theoretical computer science, providing applications in various branches of mathematics, physics, biology and engineering. Lovász is the President of the Hungarian Academy of Sciences, member of several academies of sciences, numerous scientific societies, and editorial boards. He has been awarded the Fulkerson Prize twice (1982, 2012), first for *"the ellipsoid method and its consequences in combinatorial optimization"* [2, 11], later for *"characterizing subgraph multiplicity in sequences of dense graphs"* [2, 16].

The Wolf Prize was given to him in 1999 *"for his outstanding contributions to combinatorics, theoretical computer science and combinatorial optimization"* [6]. Among many other prizes, he also received the Knuth Prize (1999) for his *"impact on the theory of algorithms"* [1] and the Kyoto Prize (2010) *"for outstanding contributions to mathematical sciences based on discrete optimization algorithms"* [3]. It would be difficult to list all the scientific achievements of Lovász but some of his main results include the proof of the weak perfect graph theorem [14], the proof of Kneser's conjecture [15], Lovász local lemma [10, 20], the Lenstra-Lenstra-Lovász lattice basis reduction algorithm (LLL-algorithm) [13] which has applications in modern cryptography [9].

The aim of this paper is twofold: first we illustrate the collaboration network of Lovász in Section 2. Furthermore, in Section 3 we consider all publications that refer to the work of Lovász and illustrate his great influence on thousands of scientists. In Section 4 we build a co-authorship network based on the citing documents.

2 Co-authorship network of Lovász

The vertex set of the co-authorship network of László Lovász is formed by all scientists who have at least one joint scientific work (article, book or book chapter, for simplicity, called paper) with Lovász according to the Hungarian bibliographic database MTMT [4]. Two vertices are linked by a single edge if and only if the corresponding authors have at least one joint work that is also co-authored by Lovász. The absence of an edge between two scientists in this network does not necessarily imply that they have no joint work, it just means that they have no joint papers that are also co-authored by Lovász.

This network has 155 vertices (the number of co-authors of Lovász) and 183 edges. The co-authorship network of Lovász indicates a collaboration with an unusually high number of scientists. There are 17 isolated vertices in the graph, corresponding to the scientists who have only two-authored joint papers with Lovász. The three largest connected components are of size 46, 11 and 10, respectively.

Some of the highest degree vertices in this network are A. Schrijver (11), K. Vesztergombi (9), É. Tardos (7) and R. Kannan (7). We mention here that A. Schrijver has 24 co-authored scientific works with Lovász. Other frequent co-authors of Lovász are B. Korte (with 16 joint papers), K. Vesztergombi (14), R. Kannan (11), B. Szegedy (10) and M. Simonovits (10).

Definition 1. *The betweenness centrality of a vertex x is*

$$C_B(x) := \sum_{s \neq x \neq t \in V} \frac{g_{st}(x)}{g_{st}},$$

where g_{st} is the total number of geodesics between the nodes s and t, $g_{st}(x)$ is the is the number of geodesics connecting s and t that contain x.

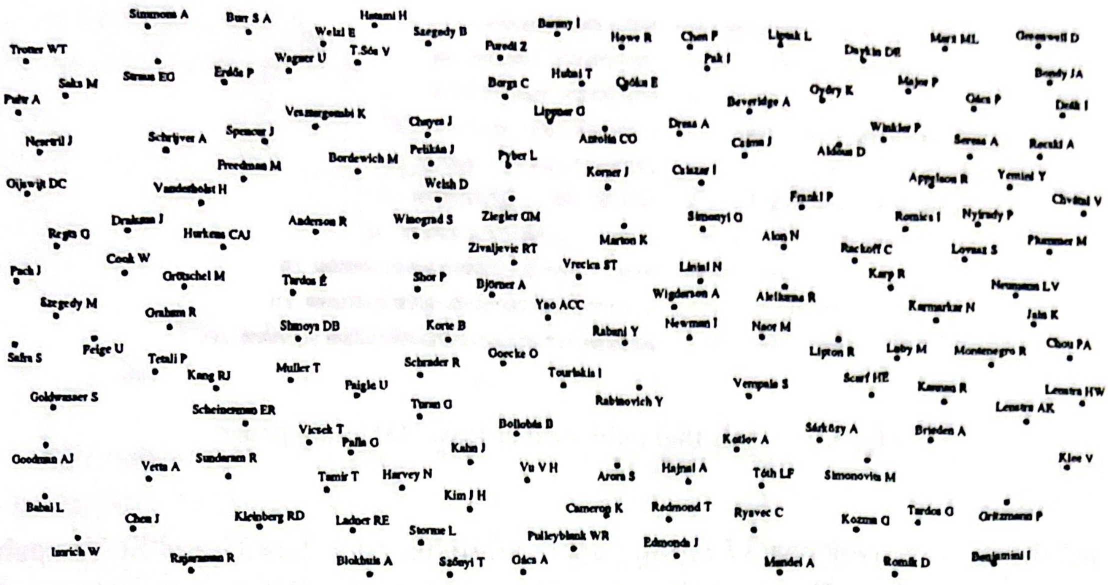

Fig. 1. The co-authorship network of László Lovász constructed with the Igraph package. We note that Lovász has a joint paper with all the above authors but we did not add him to the graph for the sake of simplicity.

Nodes with high betweenness centrality have immense influence over the transmission of information, under the assumption that information follows the shortest path. The highest betweenness scores correspond to A. Schrijver (568), É. Tardos (512), A. Björner (313) and K. Vesztergombi (313).

3 Elementary statistics of citing works

Lovász has a lot of influential and exceptionally highly cited papers and books. In this section we consider all the scientific documents that refer to any papers of Lovász. According to Web of Science [5] there are 6902 citing documents written by 7988 different authors (downloaded on 27 February 2018). The 6902 works were published in 1674 different journals/proceedings/books indicating the diversity of domains that build on the work of Lovász. Figure 3 gives the broad spectrum of journals publishing at least 100 citing papers.

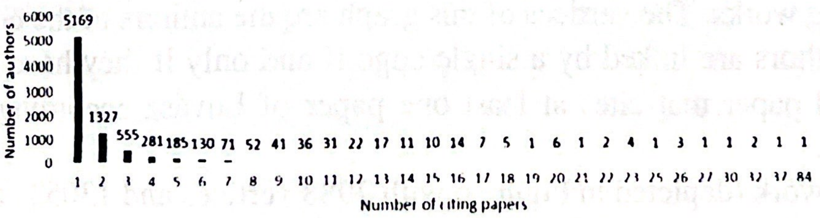

Fig. 2. Number of citing papers per author

Figure 2 shows a histogram providing the number of citing papers per author. The maximum number of citing papers per author is 84 corresponding to Lovász

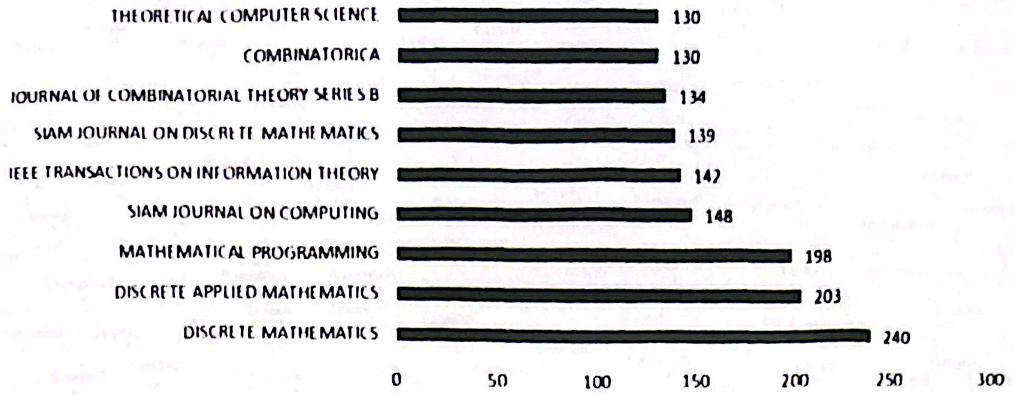

Fig. 3. Journals that published at least 100 citing papers

himself, A. Schrijver has 37 citing papers while N. Alon has 32 and S. Vempala has 30 such papers. Figure 4 illustrates the number of collaborating authors per citing works. It can be seen that most of these works have two authors.

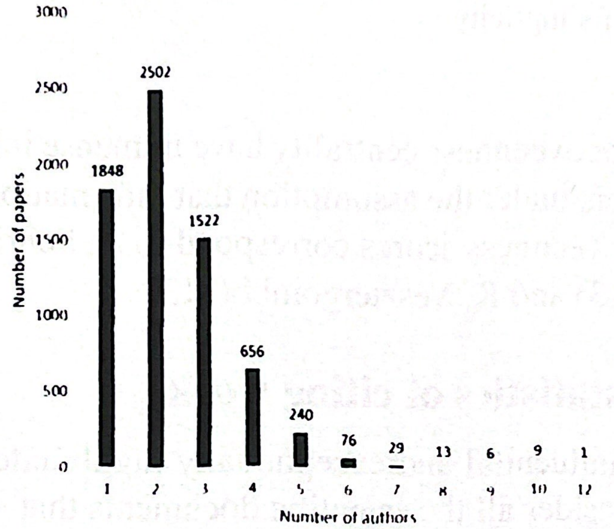

Fig. 4. Number of collaborating authors per paper

4 Co-authorship network of the citing authors

In this section we study the co-authorship network determined by the above mentioned citing works. The vertices of this graph are the authors of the citing papers, and two authors are linked by a single edge if and only if they have at least one co-authored paper that cites at least one paper of Lovász according to Web of Science [5].

The network (depicted in Figure 6 with 7988 vertices and 13053 edges) shows the very broad impact of Lovász in the scientific world. The average degree of this network is approximately 3.26. There are 556 isolated vertices in the network, indicating the number of scientists who have only sole-authored papers that cite Lovász. The degree distribution of the network is presented in Figure 5.

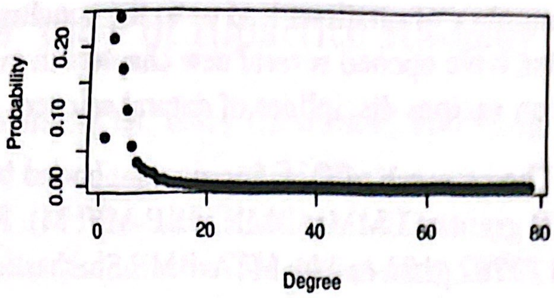

Fig. 5. The degree distribution of the network of citing authors

We can observe that there is a giant component with 4097 vertices. The second largest component contains only 27 scientists, so we can state that there is a strong collaboration between the citing authors. The highest degree scores are L. Lovász (77), G. Mózsik (66), T. Jávor (50) and N. Alon (43). The high degrees of G. Mózsik and T. Jávor indicate a very broad impact of Lovász in discoveries of Gastroenterology. The highest betweenness centrality scores correspond to L. Lovász (2020312), N. Alon (972846) and S. Vempala (790038).

We used Walktrap Algorithm to detect the main communities of the network [19]. The three largest communities identified by Walktrap Algorithm contain 874, 179 and 172 vertices, respectively. The center (the one with highest betweenness centrality) of the largest community is L. Lovász himself.

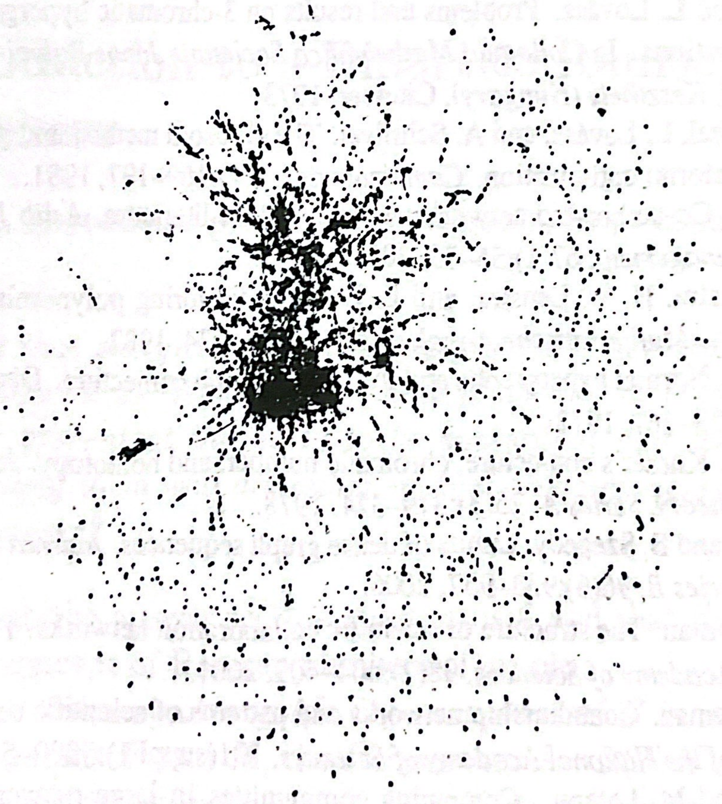

Fig. 6. The co-authorship network determined by the citing works

The respectable number of citations lead us to the conclusion that the stimulating results of Lovász have opened several new chapters in mathematics, having a deep-going impact on various disciplines of natural sciences.

Acknowledgment. The research of O. Fülöp was supported by the BME- Artificial Intelligence FIKP grant of EMMI (BME FIKP-MI/FM). R. Molontay is supported by NKFIH K123782 grant and by MTA-BME Stochastics Research Group.

References

1. 1999 Knuth Prize. https://www.sigact.org/Prizes/Knuth/1999.html. Acc: 10/02/18.
2. D. R. Fulerson Prize. http://www.ams.org/profession/prizes-awards/ams-prizes/fulkerson-prize. Acc: 10/02/18.
3. Kyoto Prize. https://www.kyotoprize.org/en/laureates/laszlo_lovasz/. Acc: 10/02/18.
4. Magyar Tudományos Müvek Tára. https://www.mtmt.hu/.
5. Web of Science. https://webofknowledge.com/.
6. Wolf Prize. https://en.wikipedia.org/wiki/Wolf_Prize_in_Mathematics. Acc: 10/02/18.
7. B. Barabás, O. Fülöp, R. Molontay, and G. Pályi. Impact of the discovery of fluorous biphasic systems on chemistry: A statistical and network analysis. *ACS Sustainable Chemistry & Engineering*, 5(9):8108–8118, 2017.
8. A.-L. Barabási, H. Jeong, Z. Néda, E. Ravasz, A. Schubert, and T. Vicsek. Evolution of the social network of scientific collaborations. *Physica A: Statistical mechanics and its applications*, 311(3-4):590–614, 2002.
9. G. Baumslag, B. Fine, M. Kreuzer, and G. Rosenberger. *A course in mathematical cryptography*. Walter de Gruyter GmbH & Co KG, 2015.
10. P. Erdős and L. Lovász. Problems and results on 3-chromatic hypergraphs and some related questions. In *Colloquia Mathematica Societatis Janos Bolyai 10. Infinite and Finite Sets, Keszthely (Hungary)*. Citeseer, 1973.
11. M. Grötschel, L. Lovász, and A. Schrijver. The ellipsoid method and its consequences in combinatorial optimization. *Combinatorica*, 1(2):169–197, 1981.
12. S. Kumar. Co-authorship networks: a review of the literature. *Aslib Journal of Information Management*, 67(1):55–73, 2015.
13. A. K. Lenstra, H. W. Lenstra, and L. Lovász. Factoring polynomials with rational coefficients. *Mathematische Annalen*, 261(4):515–534, 1982.
14. L. Lovász. Normal hypergraphs and the perfect graph conjecture. *Discrete Mathematics*, 2(3):253–267, 1972.
15. L. Lovász. Kneser's conjecture, chromatic number, and homotopy. *Journal of Combinatorial Theory, Series A*, 25(3):319–324, 1978.
16. L. Lovász and B. Szegedy. Limits of dense graph sequences. *Journal of Combinatorial Theory, Series B*, 96(6):933–957, 2006.
17. M. E. Newman. The structure of scientific collaboration networks. *Proceedings of the National Academy of Sciences*, 98(2):404–409, 2001.
18. M. E. Newman. Coauthorship networks and patterns of scientific collaboration. *Proceedings of the National Academy of Sciences*, 101(suppl 1):5200–5205, 2004.
19. P. Pons and M. Latapy. Computing communities in large networks using random walks. In *Int. symp. on computer and information sci.*, pages 284–293. Springer, 2005.
20. J. Spencer. Asymptotic lower bounds for Ramsey functions. *Discrete Mathematics*, 20:69–76, 1977.