

Who is Who in Phylogenetic Networks: Articles, Authors and Programs

TUSHAR AGARWAL¹, PHILIPPE GAMBETTE^{2,*}, DAVID MORRISON³

¹Computer Science and Engineering, Indian Institute of Technology Ropar, Punjab 140001, India; ²Université Paris-Est, LIGM (UMR 8049), UPEM, CNRS, ESIEE, ENPC, Marne-la-Vallée 77454, France; and ³Systematic Biology, EBC, Uppsala University, Norbyvägen 18D, Uppsala 75236, Sweden

* Correspondence to be sent to: Philippe Gambette, Université Paris-Est, LIGM (UMR 8049), UPEM, CNRS, ESIEE, ENPC, Marne-la-Vallée 77454, France; E-mail: philippe.gambette@u-pem.fr

Received 00 XXXXX 0000; reviews returned 00 XXXXX 0000; accepted 00 XXXXX 0000

Associate Editor: XXXX XXX

Abstract.—The phylogenetic network emerged in the 1990s as a new model to represent the evolution of species in the case where coexisting species transfer genetic information through hybridization, recombination, lateral gene transfer, etc. As is true for many rapidly evolving fields, there is considerable fragmentation and diversity in methodologies, standards and vocabulary in phylogenetic network research, thus creating the need for an integrated database of articles, authors, techniques, keywords and software. We describe such a database, “Who is Who in Phylogenetic Networks”, available at <http://phylnet.univ-mlv.fr>. “Who is Who in Phylogenetic Networks” comprises more than 600 publications and 500 authors interlinked with a rich set of more than 200 keywords related to phylogenetic networks. The database is integrated with web-based tools to visualize authorship and collaboration networks and analyze these networks using common graph and social network metrics such as centrality (betweenness, eigenvector, degree and closeness) and clustering. We provide downloads of raw information about entries in the database, and a facility to suggest modifications and contribute new information to the database. We also present in this article common use cases of the database and identify trends in the research on phylogenetic networks using the information in the database and textual analysis. [Phylogenetic network, co-authorship network, social networks, phylogenetic networks software, phylogenetic networks keywords.]

1 The phylogenetic network has gained popularity in
2 the past two decades as a model of evolution capable
3 of accounting for vertical inheritance as well as gene
4 flow events such as recombination, hybridization and
5 horizontal gene transfer, which the simple tree-based
6 model fails to do. The rapid evolution of the body of
7 knowledge related to, and the community working on,
8 phylogenetic networks has led to significant variety in
9 many phylogenetic methodologies, such as reconstruction
10 and classification, and software to compute, evaluate,
11 compare, and visualize phylogenetic networks. Although
12 some surveys (Lapointe 2000; Makarenkov et al. 2006;
13 Morrison 2010; Huson and Scornavacca 2011; Nakhleh
14 2013; Morrison 2014) and books (Huson et al. 2011;
15 Morrison 2011; Dress et al. 2012; Gusfield 2014) describe
16 this variety, “Who is Who in Phylogenetic Networks” is
17 the first resource of its kind aiming to consolidate this
18 diversity into an easily navigable database.

19 The website was started in 2007 as an interactive
20 bibliographic database of phylogenetic networks
21 research, based on an open source project, BibAdmin
22 (<https://gforge.inria.fr/projects/bibadmin/>).
23 The code has been extensively extended to incorporate
24 capabilities to draw word clouds and network
25 visualizations. New graphs and sections were also
26 added to the website to present the raw information in
27 the database in a more meaningful way.

In addition to providing information about the community working on phylogenetic networks, “Who is Who in Phylogenetic Networks” makes available an easy-to-use interface to study the evolution of a new, swiftly growing scientific community. This database and the associated website are intended to serve as an encyclopedic and bibliographic resource of information about the community, tools, models and methods related to phylogenetic networks. Such a resource has inherent value for current members of the phylogenetic community, particularly researchers and students new to the field, as well as the community working on biological methods in general.

AUTHORS AND KEYWORDS IN THE DATABASE

Authors

Each author’s entry in the database has associated with it a picture, the author’s country of origin as determined automatically from the domain name of the author’s website, a link to the author’s personal or professional homepage, as well as a link to view his or her publications in Google Scholar. Each publication’s entry in the database consists of, in addition to essential data about the publication itself, a set of keywords, a DOI link, and an abstract, if available.

Keywords

Publications in the database are manually tagged by keywords, which help identify articles or methods based on: (i) the nature of the problem solved in an article (reconstruction, consensus, labeling, comparison, generation, visualization, etc.) and its computational complexity (NP-complete, APX-hard, polynomial); (ii) the nature of algorithms given in an article (“exponential algorithm” and “FPT” – for “fixed-parameter tractable” – are approaches to solving NP-hard problems exactly, whereas “approximation” or “heuristic” algorithms aim to find approximate solutions); (iii) the nature of input data; (iv) the restrictions on subclasses of networks studied in the article (e.g. “galled trees”, “tree-child networks”, etc.); (v) the existence of an implementation, indicated by the tag “software”; (vi) the names of software, articles and methods used or implemented (keywords starting with the word “Program”). A definition is provided for technical keywords. Furthermore, keywords act as a convenient and meaningful navigational aid in the website, as described in several use cases below.

USE CASES

The main page of the “Who is Who in Phylogenetic Networks” highlights four use cases, corresponding to an action users might wish to take or a type of information they might wish to obtain: find experts, explore research, discover software and follow the community.

Find Experts

This section comprises two types of co-authorship network visualizations: first, a set of precomputed graphs augmented with various social network metrics; and second, a set of dynamic graphs with metrics computed directly on the user’s computer.

Each node in a precomputed graph is tagged with measures of degree, authority, hub, number of triangles containing that node as a vertex, betweenness centrality, closeness centrality, eigenvector centrality, clustering coefficient and eccentricity (for definitions, see e.g. Estrada 2015). All of these metrics are computed using the open source network analysis tool Gephi (Bastian et al. 2009). The web interface makes it possible for the user to see the global evolution of the phylogenetic network community by displaying the network corresponding to any year from 1990 through 2015.

The dynamic graphs (Fig. 1) provide the user sufficient flexibility to display only those nodes fulfilling customizable structural and temporal constraints. It is possible to display the co-authorship network for any arbitrary range of time, and focus only on authors with a configurable minimum number of publications. Nodes can be colored along a linear gradient depending on the values of the degree, the number of triangles containing that node as a vertex, or the centrality measures mentioned above. This makes the dynamic

graph amenable to visual analysis, and enables easy identification of significant nodes in the community. For instance, the social network metrics available enable visual identification of nodes that are “central” in their communities, linked to many other nodes, or act as “bridges” between communities. Nodes that do not pass the specified criterion of a chosen minimum number of publications are ignored in the calculation of the color gradient. The user may also choose to highlight the authors belonging to a particular country, or see a detailed research profile and the list of indexed articles of an author, simply by clicking on the corresponding node.

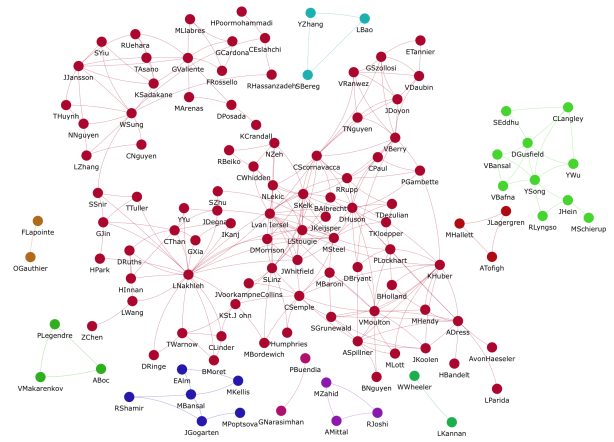


FIGURE 1. A screenshot of a portion of the 2014 co-authorship network in “Who is Who in Phylogenetic Networks”.

Information about journals and conferences the phylogenetic networks community publishes in or meets at is presented in the form of tag clouds. In addition to providing an exhaustive listing of publication venues, these give visual hints about the relative importance of journals and conferences, and may help to identify possible venues for submission, or find articles on phylogenetic methods. The size and color of a word in a tag cloud varies across a logarithmic scale, with larger size and warmer colors representing a greater number of publications in the corresponding journal or conference.

The entire community working on phylogenetic networks is depicted pictorially as a collage of authors’ photos. The dimensions of an author’s picture represent the number of publications by that author weighted by the number of co-authors on each publication.

The “Find Experts” section also consists of a co-authorship network visualization enriched with information about keywords in the database, and with the capability to color nodes, representing authors, across a gradient depending on their “focus”, the fraction of total publications of the corresponding author tagged with a keyword, or their “prolificacy”, the total number of publications of the corresponding author tagged with a keyword, if they satisfy a customizable threshold of minimum number of publications.

Explore Research

Publications in the database are accompanied by information on their media of publication or presentation, such as books, journals, conferences and theses. This section includes bar charts illustrating the trend of all indexed publications about phylogenetic networks or those including a particular keyword.

The “Explore research” section also consists of a word-cloud of keywords, and also a “tree cloud” (Gambette and Véronis 2010) plus a natural extension of this, a “network cloud” built using NeighborNet (Bryant and Moulton 2004). These provide a global view of the database, and display all keywords structured in the form of a tree depicting their semantic relationships, automatically deduced from their co-occurrence in the database. Here, too, the size and color of a word in a word-cloud varies along a logarithmic scale, with larger size and warmer color representing a greater number of publications containing the corresponding keyword.

Discover Software

The structure of the website and the presence of keywords makes it possible for biologists to identify one or more programs suitable to study their data, which might be in a particular format or structure. A network depicting relationships between input data and programs aids this process. Each keyword corresponding to a certain type of input data (starting with “from”, such as “from sequences”, “from distances”, “from rooted trees”, etc.) links to keywords representing software (starting with “Program”, such as “Program SplitsTree”, “Program Phylonet”, “Program TCS”, etc.). Each program has a short description including a download link.

Follow Community

Using the “Follow community” feature, a user can receive an update whenever a particular author’s article is indexed or when a new article is published by any author in the community.

MAPPING THE PHYLOGENETIC NETWORKS RESEARCH AND COMMUNITY

In this section, we demonstrate how the “Who is Who in Phylogenetic Networks” database can be used to analyze trends about the community of researchers working on phylogenetic networks. We focus first on their collaborations, and second on their research interests.

Evolution of the Co-authorship Network

The co-authorship network provided on the “Who is Who in Phylogenetic Networks” website shows how individual research groups working on phylogenetic networks started developing inter-group research collaborations,

which are represented as connected components in the graph. Increasing collaboration results in the merging of connected components over the years from 1991 through 2015. In fact, it is natural that, as more and more publications are taken into account to build this network, its largest connected component (a “giant” component) becomes larger with time.

In order to analyze in greater detail the evolution of the global structure of the co-authorship network, we focus on uniform-sized time slices, rather than consider all publications added since the oldest one. Therefore, we focus on the 2005-2015 period, where the number of publications is great enough (more than 30 articles per year). We generated the co-author graph for slices or periods of 5 years starting from 2005 (2005 through 2009, 2006 through 2010 and so on), connecting two authors if they have published at least three publications together in a slice or period. We chose this threshold because it implies that the linked researchers have worked on more than one project together; as the conference versions of journal papers are referenced on the website, choosing a threshold of two publications would not have been high enough for this purpose.

The main connected component of the graph reveals interesting information about the structure of collaborations over the years¹. For instance, in the 2005-2009, 2006-2010 and 2007-2011 periods, it always contains only Luay Nakhleh and his co-authors. Furthermore, Luay Nakhleh is an author of almost all publications (except one) explaining the edges in these connected components. However, for the later years, the main connected components do not contain such a single vertex that is adjacent to all of the other vertices. Furthermore, the size of the connected component in the first three periods is at most ten, whereas for the three last periods, it ranges between 12 and 15. This shows that in recent years, several distinct groups, especially in Europe (France, the Netherlands, the UK, Germany and Sweden), have started collaborating to conduct research on phylogenetic networks.

Mapping the Phylogenetic Network Research Topics

We also study the trends and characteristics of phylogenetic networks research topics, by using the Digital Object Identifiers (DOIs) stored in the “Who is Who in Phylogenetic Networks” database. The DOIs allow easy access to the abstracts of the publications, using scientific databases such as the Web of Science (<https://www.webofknowledge.com/>) or Scopus (<https://www.scopus.com/>). Again, we focus on the 2005-2015 period, to have a high enough and stable number of publications in each year. Using Scopus, we found the abstracts for 305 publications in this period.

First, we performed a factor analysis on the abstracts grouped together by year (see Fig. 2), using Lexico

¹The corresponding complete dataset is available at <https://goo.gl/vA8U6G>.

3 (<http://www.lexi-co.com>). In the factor graph, we
 2 find a time trend, with the years 2005 through 2009 on
 3 the right side, years 2010 and 2011 in the middle, and
 4 years 2012 through 2015 on the left side. Vocabulary
 5 that is significantly overrepresented in the 2005-2009
 6 period includes “recombination”, “hgt”, “sequences”,
 7 “consensus” and “metrics”. In the 2012-2015 period,
 8 “reconciliation”, “trinets”, “cost”, “duplication”, “loss”
 9 and “binary” are overrepresented. This reflects the
 10 recent development of efficient methods to reconstruct
 11 reconciliation scenarios taking into account not only
 12 lateral gene transfer but also duplication and loss, as well
 13 as the introduction of new combinatorial objects related
 14 to networks, like trinets.

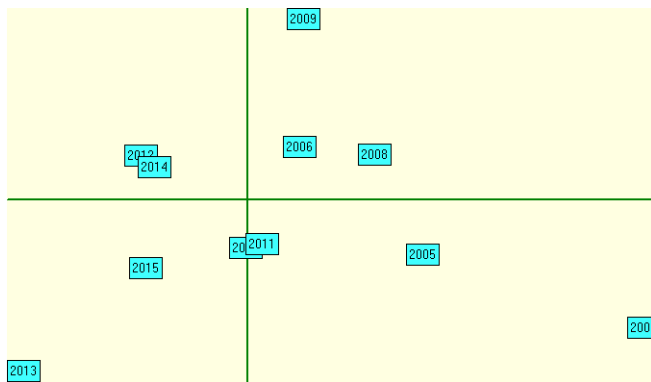


FIGURE 2. Factor analysis of the abstracts of 305 publications about phylogenetic networks in the 2005-2015 period, grouped by year.

15 Second, we performed the factor analysis of all
 16 documents, as shown in Fig. 3. The graph highlights
 17 interesting characteristics of the phylogenetic networks
 18 research topics. The main axis distinguishes between
 19 the more algorithmic or mathematical papers on the
 20 right side (“n”, “networks”, “algorithm”, “phyloge-
 21 netic”, “rooted”, “time”, “vertices”, “number”) and
 22 the more biological papers on the left side (“gene”,
 23 “hgt”, “reconciliation”, “transfer”, “methods”, “infe-
 24 rence”, “species”, “lineage”). The second axis seems to
 25 distinguish between approaches that explicitly recon-
 26 struct abstract or explicit phylogenetic networks at
 27 the top (“networks”, “split”, “phylogenetic”, “circular”,
 28 “class”, “taxa”, “cluster”, “trinets”, “quartet”), and
 29 reconciliation scenarios, with a special focus on the
 30 model, at the bottom (“gene”, “hgt”, “reconciliation”,
 31 “lineage”, “lgt”, “transfer”, “species”, “duplication”,
 32 “model”). Note that the isolated paper in the bottom
 33 right corner is very mathematical and deals with proving
 34 a formula, with this formula presented in this article’s
 35 abstract, and this explains its unusual position in the
 36 representation. Our results do not change if we remove
 37 this article’s abstract from the corpus.

38 A similar kind of analysis can be used on a subset of
 39 publications to focus on a more specific topic, and this
 40 can be useful, for example, when composing a research
 41 article, where it may be helpful to provide an overview
 42 of the research done so far, or the state of the art.

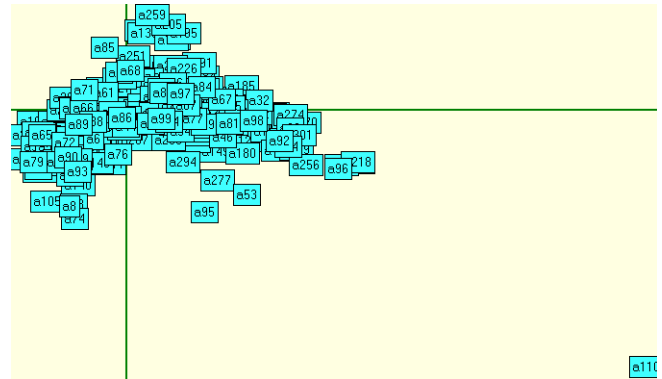


FIGURE 3. Factor analysis of the abstracts of 305 publications about phylogenetic networks in the 2005-2015 period.

43 AVAILABILITY

44 “Who is Who in Phylogenetic Networks” is freely
 45 available online at <http://phylnet.univ-mlv.fr>. The
 46 database and website code is open source and available
 47 at <https://github.com/tushar-agarwal/phylnet>.

48 CONCLUSION

49 We described “Who is Who in Phylogenetic Net-
 50 works”, a database associated with web-based tools that
 51 allow users to explore the community of researchers
 52 working on phylogenetic networks and the research done
 53 in this field. Not only is the database of inherent value
 54 in trying to present the diversity in the methodologies
 55 and vocabulary in research on phylogenetic networks in a
 56 single location, but it is useful both for researchers work-
 57 ing on designing new methods involving phylogenetic
 58 networks, and for bioinformaticians who wish to obtain
 59 an overview of existing methods to perform analyses on
 60 their data. We also showed how the content present in
 61 this database can be used for general analyses about the
 62 research, and the social network of researchers, in this
 63 field.

64 REFERENCES

- 65 Mathieu Bastian, Sebastien Heymann, and Mathieu Jacomy.
 66 Gephi: An open source software for exploring and manipulating
 67 networks. In *International AAAI Conference on Weblogs and
 68 Social Media (ICWSM’09)*, 2009.
 69 David Bryant and Vincent Moulton. Neighbor-net: an agglome-
 70 rative method for the construction of phylogenetic networks.
 71 *Molecular biology and evolution*, 21(2):255–265, 2004.
 72 Andreas W. M. Dress, Katharina Huber, Jacobus Koolen, Andreas
 73 Spillner, and Vincent Moulton. *An Introduction to Phylogenetic
 74 Combinatorics*. Cambridge University Press, 2012.
 75 Ernesto Estrada. Introduction to complex networks: Structure
 76 and dynamics. In Jacek Banasiak and Mustapha Mokhtar-
 77 Kharroubi, editors, *Evolutionary Equations with Applications
 78 in Natural Sciences*, pages 93–131. Springer International
 79 Publishing, Cham, 2015.
 80 Philippe Gambette and Jean Véronis. Visualising a text with a tree
 81 cloud. In Hermann Locarek-Junge and Claus Weihs, editors,
 82 *Classification as a Tool for Research: Proceedings of IFCS 2009*,
 83 pages 561–569, Berlin, Heidelberg, 2010. Springer.

- 1 Dan Gusfield. *ReCombinatorics: The Algorithmics of Ancestral*
2 *Recombination Graphs and Explicit Phylogenetic Networks*.
3 MIT Press, 2014.
- 4 Daniel H. Huson and Celine Scornavacca. A survey of combina-
5 torial methods for phylogenetic networks. *Genome Biology and*
6 *Evolution*, 3:23–35, 2011.
- 7 Daniel H. Huson, Regula Rupp, and Celine Scornavacca. *Phy-*
8 *logenetic Networks: Concepts, Algorithms and Applications*.
9 Cambridge University Press, 2011.
- 10 François-Joseph Lapointe. How to account for reticulation events
11 in phylogenetic analysis: A review of distance-based methods.
12 *Journal of Classification*, 17:175–184, 2000.
- 13 Vladimir Makarenkov, Dmytro Kevorkov, and Pierre Legendre.
14 Phylogenetic network construction approaches. In Dilip K.
15 Arora, Randy M. Berka, and Gautam B. Singh, editors, *Applied*
16 *Mycology and Biotechnology*, volume 6, pages 61–97. Elsevier,
17 2006.
- 18 David A. Morrison. Phylogenetic networks in systematic biology
19 (and elsewhere). In R.M. Mohan, editor, *Research Advances*
20 *in Systematic Biology*, pages 1–48. Global Research Network,
21 Trivandrum, India, 2010.
- 22 David A. Morrison. *Introduction to Phylogenetic Networks*. RJR
23 Productions, 2011.
- 24 David A. Morrison. Phylogenetic networks: A review of methods
25 to display evolutionary history. *Annual Research & Review in*
26 *Biology*, 4(10):1518–1543, 2014.
- 27 Luay Nakhleh. Computational approaches to species phylogeny
28 inference and gene tree reconciliation. *Trends in Ecology and*
29 *Evolution*, 28(12):719–728, 2013.