

Filipi N. Silva

Researcher • Data scientist • Software developer

Ph.D. in Computational Physics

Research Scientist at Indiana University Network Science Institute



Hi!

I'm Filipi Nascimento Silva, Ph.D. in computational physics, currently working as a research scientist at the Indiana University Network Science Institute (IUNI).

Research

My interests include developing and implementing new techniques for analyzing, modeling and understanding real-world systems through complex networks, machine learning and data visualization.

Experience

I've published papers and developed software on many scientific fields, including bioinformatics, text analysis, scientometry, information science, and urban networks. I'm also the creator of the Networks 3D visualization tool.

Future

I'm looking for opportunities around the world in which I can continue to develop my skills while also doing research on interdisciplinary topics or bringing amazing products to life. I'm interesting in careers at the university, industry, or a combination of both.

Specs.

FULL NAME Filipi Nascimento Silva

CONTACT Indiana University Network Science Institute (IUNI)
INFORMATION Bloomington, IN 47408, USA
+1 (812) 855-6428
filipinascimento.github.io
filipinascimento@gmail.com

LANGUAGES Portuguese (native) and English

CITIZENSHIP Brazilian

EDUCATION Ph.D. in Physics, Speciality: *Computational Physics*
2011 – 2015
São Carlos Institute of Physics (University of São Paulo)

MSc in Physics, Speciality: *Computational Physics*
2007 – 2009
São Carlos Institute of Physics (University of São Paulo)

B.S in Physics, Speciality: *Computational Physics*
2003 – 2006
São Carlos Institute of Physics (University of São Paulo)

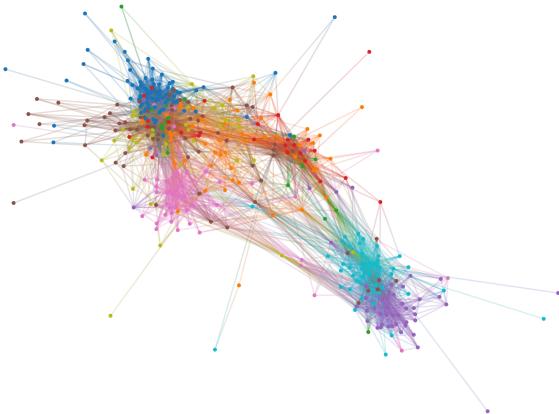
LINKEDIN <http://linkedin.com/in/filipinascimento>

RESEARCHGATE https://www.researchgate.net/profile/Filipi_Silva2

GOOGLE SCHOLAR <https://scholar.google.com.br/citations?user=fhWJEysAAAAJ>

METRICS 33 publications in indexed journals
2 book chapters
246 citations (Web of Science)
290 citations (SCOPUS)
577 citations (Google Scholar)

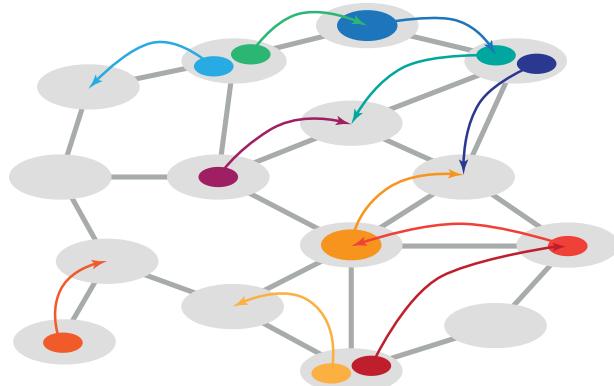
Experience



Research Scientist

IUNI - Indiana University (IU)
2019 - now

Currently studying the dynamics of science itself by tracking how scientific fields evolve over time. Also working on other projects related to building networks from similarity data, such as networks of politicians connected by vote correlation. Also developing a new set of interactive web-based network visualization tools for researchers.



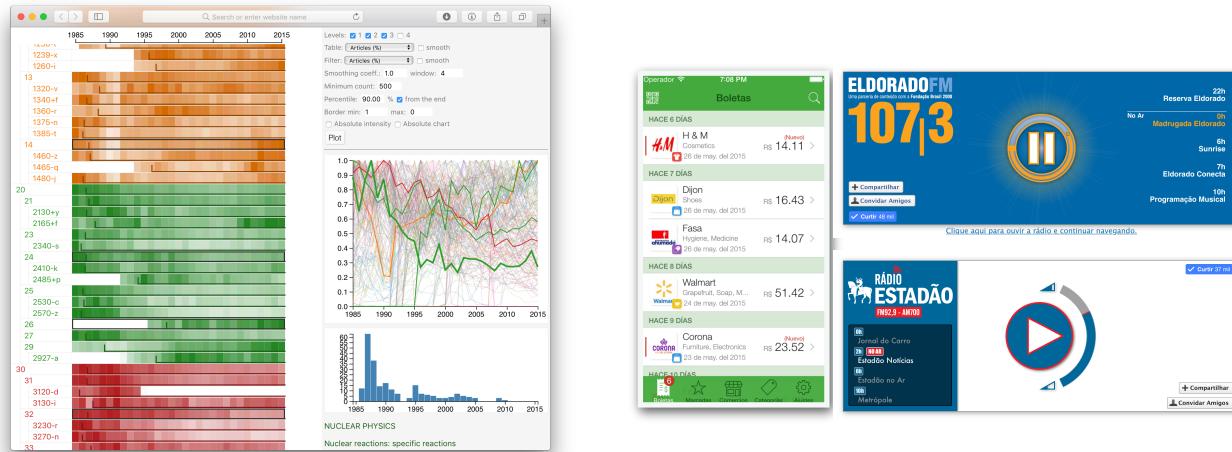
Postdoctoral Fellow

IFSC1 - University of São Paulo (USP)
2015 - 2018

Studying dynamics occurring or driving the evolution of *complex networks* along time for a diverse range of datasets, such as texts, cities, financial market and biological systems. Also developing new web-based tools and *libraries* for *network analysis* and *visualization*, as well as new *theoretical approaches* in complex networks.

Advisor: Luciano da F. Costa
(grants by FAPESP)

Experience (cont)



Visiting Researcher

SICE¹ - Indiana University
2017 - 2018

Currently studying the evolution of scientific fields along time based on information coming from content (such as texts), citation networks and popularity metrics. Our main goal is to predict the emergence of new scientific fields and understand its dynamics. For that, we developed a web application to explore popularity time-series obtained for scientific fields and properties from citation networks.

Supervision: Filippo Menczer
(grants by FAPESP)

iOS and Web Developer

Freelancer
2009-2010 and 2019

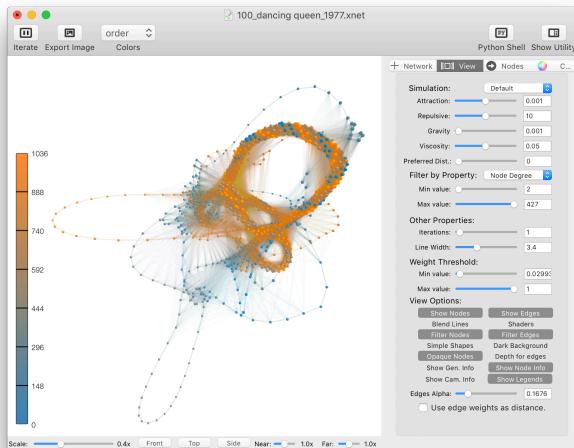
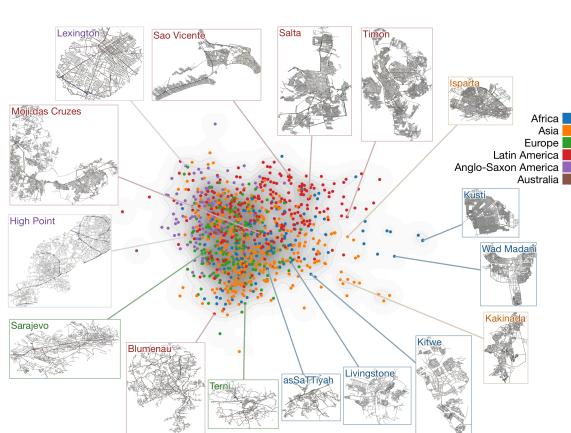
Acting as freelancer consultant developer of solutions for *iOS*. Started developing an *entertainment* and *visualization library* for *iOS* devices written in *Objective-C* and using *OpenGL ES*. Currently developing an *iOS* game called *Gridland*. Notable clients: Paperless², Gtechnologies, Plus-TI, and Rádio Eldorado³.

1 - School of Informatics, Computing and Engineering

2 - www.paperlessdobrasil.com.br

3 - www.facebook.com/radioeldorado

Experience (cont)



Data Scientist

Freelancer for Bike da Firma
2015

Worked as a freelancer consultant and developer of *data science* solutions for Bike da Firma¹. Conceived and implemented *classification techniques* employed to *extract patterns* of information retrieved from mobile devices, such as *geolocation* and *accelerometer data*.

Ph.D. Thesis

IFSC - University of São Paulo (USP)
2011 - 2015

Studied the *multidimensional structure* of *complex networks* such as *fractals* and *high dimensional geographic networks*. We analyzed many real-world systems, such as gene to gene correlation networks, academic publication data and geographic networks. During this time I also improved and optimized the algorithms behind our network visualization tool leading to a visualizer tool for the web.

Advisor: Luciano da F. Costa
(grants by FAPESP)

Among the three awarded theses in exact sciences of USP in 2015/2016.²

1 - www.bikedafirma.com/en/

2 - <https://jornal.usp.br/universidade/usp-anuncia-vencedores-do-premio-tese-destaque-2017/>

Experience (cont)

Scientific initiation Studied the multiscale structure of complex network derived from complex systems by means of IFSC - USP hierarchical node-centered measurements.

2007 - 2009 Developed a framework to obtain Hierarchical (Concentric) properties from complex networks and published an article in Journal of Statistical Physics.
Supervision: Luciano da Fontoura Costa.
Advisor: Luciano da F. Costa
(grants by CAPES)

Scientific initiation Ported RoundMidnight - EXAFS Datafiting software from Mac OS X to Windows.

IFSC - USP Advisors: Valmor R. Mastelaro and Alain Michalowicz
2004 - 2005 (grants by CNPq)

Misc. experience

TEACHING Assistant lecturer internship (Programa PAE) - 2014

EXPERIENCE Grants by CAPES

IFSC - University of São Paulo

Course: Mathematical and Computational Modeling

Duration: 120 hours

Supervision: Prof. Luciano da F. Costa

Conducted the workshop: Introduction to Interactive Visualization of Data and Complex Networks

5^a Semana da Física

IFSC - University of São Paulo

STUDY Visiting researcher at Northeastern University, 2016

ABOARD Duration: 1 week.

Visiting researcher at Boston University, 2016

Duration: 1 week.

Supervision: Prof. Eugene H. Stanley

Visiting researcher at Krasnow Institute (GMU), 2016

Duration: 1 week.

Visiting student at Harvard Medical School, 2012

Duration: 1 week.

Visiting student at Boston University, 2012

Duration: 2 weeks.

Supervision: Prof. Eugene H. Stanley

REVIEWER Physics Letters A, Complexity, IEEE Transactions on

EXPERIENCE Network Science and Engineering, PeerJ, IEEE DSAA, Entropy, Journal of Informetrics.

Selected publications

Comin, C.H.; Peron, T.K.DM.; Silva, F. N.; Amancio, D. R.; Rodrigues, F.A. and Costa, L. da F.

Complex systems: features, similarity and connectivity. Physics Reports, 2020
doi: [10.1016/j.physrep.2020.03.002](https://doi.org/10.1016/j.physrep.2020.03.002)

Silva, F. N.; Amancio, D. R.; Bardosova, M.; Oliveira Jr., O. N.; Costa, L. da F.
Using network science and text analytics to produce surveys in a scientific
topic. Journal of Informetrics, v. 10, n. 2, p. 487 – 502, 2016
doi: [10.1016/j.joi.2016.03.008](https://doi.org/10.1016/j.joi.2016.03.008)

Silva, F.N.; Comin, C.H.; Peron, T.K.DM. ; Rodrigues, F.A.; Ye, C.; Wilson,
R.C.; Hancock, E.R. and Costa, L. da F.
Concentric network symmetry. Information Sciences, Volume 333, p. 61-80,
2015
doi: [10.1016/j.ins.2015.11.014](https://doi.org/10.1016/j.ins.2015.11.014)

Moreira-Filho, C. A.; Bando, S. Y.; Bertonha, F. B.; Silva, F. N.; Costa, L. da F.;
Ferreira, L.; Furlanetto, G.; Chacur, P.; Zerbini, M. C.; Carneiro-Sampaio, M.
Modular Transcriptional Repertoire and MicroRNA target Analyses
Characterize Genomic Dysregulation in the Thymus of Down Syndrome
Infants. Oncotarget, v. 7, n. 11, p. 7497 – 7533, 2015
doi: [10.18632/oncotarget.7120](https://doi.org/10.18632/oncotarget.7120)

Silva, F. N.; Rodrigues, F. A.; Oliveira Jr., O. N.; Costa, L. da F.
Quantifying the interdisciplinarity of scientific journals and fields
Journal of Informetrics, v. 7, n. 2, p. 469--477, 2013
doi: [10.1016/j.joi.2013.01.007](https://doi.org/10.1016/j.joi.2013.01.007)

The complete list of my publications can be found in:

<https://filipinascimento.github.io/publications/>

<http://www.researcherid.com/rid/C-7620-2012>

<https://scholar.google.com.br/citations?user=fhWJEysAAAAJ>

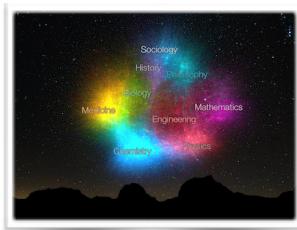
Pre-prints and recent manuscripts can be found in arXiv:

<http://goo.gl/gI5plq>

Software (cont)

Helios

2020 - now



Currently, no flexible and fast tool that implements both graph layout and network rendering is available for researchers to visualize large networks. The purpose of this project is to fill this gap by developing an advanced interactive visualization tool for networks based on the concepts employed on my previous works.

The project was separated into three main components: Helios Core, Helios Fury, and Helios Web.

Helios Core will implement, in C language, a set of fast and scalable layout techniques for network visualization. This includes force-directed methods and node embedding techniques. The core will serve as the basis to build the other components and will be available as a Python package or compilable to WebAssembly.

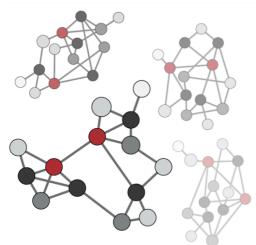
Helios Fury is a version of the rendering engine being written on top of the Fury¹ framework for Python.

A preliminary version of Helios Core is already available at:

<https://github.com/heliosnet/helios-core>

Network neuroscience apps for brainlife

2020 - now



While network neuroscience has become popular among researchers over the past few years, the brainlife platform lacks network analysis pipelines. This subproject aims to make available network analysis and visualization tools on the brainlife framework.

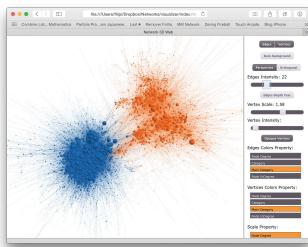
Five brainlife apps were developed and can be found in:

<https://brainlife.io/apps#network>

1 - <https://fury.gl>

Software (cont)

Network visualization tools for the web 2013 - 2019



To improve the usefulness of our visualization tools we started porting them to a new web-based environment. More specifically, we are reimplementing the visualizer using web technologies, such as WebGL and HTML5. Currently it can display graphically astounding complex networks visualizations on any recent major browser.

Interdisciplinary map of science obtained from a journals network (video).

<http://youtu.be/ipjTMy-RnvU>

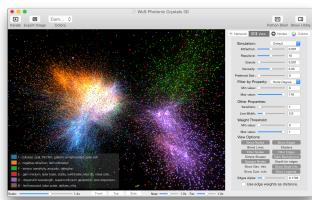
Gene expression map for people suffering from febrile epilepsy (video).

<http://youtu.be/Trb67DoLf5U>

The software source code and demonstration can be found in:

<https://filipinascimento.github.io/software/networksweb/>

Networks 3D 2009 - 2019



Networks 3D is a software under development, built to construct and interact with graphically appealing visualizations of large complex networks. Its main objective is to provide means for researchers and specialists to see and get a visual overview of the data they are working with. The tool is based on a optimized force-directed algorithm, which is used to project the networks to a 2D or 3D space, presenting results generated by the graphical processing unit in real-time.

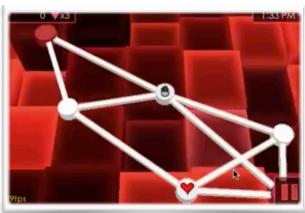
More info at the software webpage:

<https://filipinascimento.github.io/networks3d/>

Other projects

Gridland

2011 - 2015



Gridland is a game being developed by me and a friend, to be distributed initially on the App Store. It is a implementation of the famous Shannon switching machine where two players compete by securing or destroying links in a graph. We developed all aspects of the game, including the artificial intelligence with 3 levels of difficulty and a 3D graphical interface. It was written entirely in C and Objective-C.

See a video of an early state version in:

<http://youtu.be/-ivf89Oh0VU>

HighSpace

2010 - 2011



We developed a 3D scene engine on top of the Cocoa Touch frameworks and OpenGL ES. The capabilities of the engine include animated GUIs, 3D object loader, geometry representation, 3D particles engine, fast text rendering, dynamic texture atlas, keyframe animations, camera control, fast sprite rendering, etc.

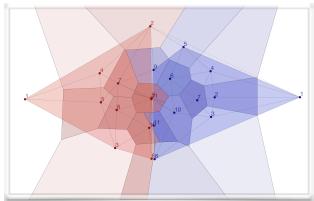
Some features of the engine are shown in this video playlist:

<http://www.youtube.com/playlist?list=PLFimqafBV-l5JvdrkczdCf73SKpBVN5fF>

or <http://goo.gl/8Rmt4>

Other projects (cont)

Other assignments Developed interactive visualizations of soccer games for data from Prof. Ricardo M. L. de Barros (UNICAMP)



<http://cyvision.ifsc.usp.br/futebolTests/voronoi40000.html>
(the download of the data may take several minutes)

Also developed software to obtain network metrics:
<https://github.com/filipinascimento/CVAccessibility>
<https://github.com/filipinascimento/CVSymmetry>

Developed the facebook apps for two major radio stations of São Paulo/Brasil (Rádio Eldorado and Rádio Estadão) :

https://www.facebook.com/radioeldorado/app_344923452275303
https://www.facebook.com/RadioEstadao/app_492239080829149

Created the website for the Cybernetic Vision Research Group (2012).

<http://cyvision.ifsc.usp.br/>

Developed a software to obtain concentric measurements of complex networks (2008).

<http://cyvision.ifsc.usp.br/concentric/>

Skill set summary

- Can read and write software in many programming languages such as: C, C++, Java, Objective-C, Python and Javascript. In particular, modern C language programming (C99 and C11) is my speciality. I also have some experience with the development of frameworks and libraries (see HighSpace and CVAccessibility/CVSymmetry). I'm also very flexible in learning and working with another programming language.
- Experience with code analysis and debugging. Including user-level knowledge of memory management techniques, such as checking for leaks, advanced allocations and deallocation patterns, reference counting, garbage collector, retain/release cycles. Also have some experience with code profiling and optimization based on time or memory.
- Can work with parallel and distributed computing on multiple machines or CPUs, encompassing libraries such as OpenMP and OpenMPI. Also have notions of MapReduce approach and GPGPU programming. (See CVAccessibility/CVSymmetry software).
- Some knowledge of GUI development and advanced knowledge of computer graphics. (see Gridland and Networks 3D). This includes shaders and advanced rendering techniques such as fake spheres and SDF.
- Experienced with machine learning methods, including supervised and unsupervised embedding and classification techniques, such as PCA, LDA, K_{nn}, SVM. I also have some experience using *2vec approaches to find good embeddings for data. (See papers "A pattern recognition approach to complex networks" and "Concentric network symmetry grasps authors' styles in word adjacency networks").
- Scientific Background:
 - General and advanced physics knowledge.
 - Advanced computational 3D geometry skills.
 - Advanced data analysis and statistics knowledge.
 - Can develop projects and content in a team of researchers.
 - Great skills and innovative mind to tackle new problems.

Skill set summary (cont)

- Some experience with natural language processing. This includes techniques to pre-process textual data, such as lemmatization, tokenization, tf-idf and embedding. Also have experience with the proper analysis of text, including topic modeling, semantic similarity and feature extraction. (See papers "Concentric network symmetry grasps authors' styles in word adjacency networks", "Mesoscopic representation of texts as complex networks" and "Using network science and text analytics to produce surveys in a scientific topic").
- Advanced knowledge of network science and in representing arbitrary datasets as complex networks. (See experience and education sections).
- Skills to construct interactive complex visualizations of arbitrary data. (See soccer games visualization, network visualization tools in WebGL and my research papers).
- Experience with the following tools and software:
 - iOS SDK.
 - Cocoa/CocoaTouch and Objective-C libraries, including UIKit and AppKit.
 - OpenGL 2.x, OpenGL ES 1.x/2.0 and OpenGL 3.2
 - Xcode.
 - LLVM/Clang compiler, GCC compiler and Intel's ICC compiler.
 - Grand Central Dispatch, multi-threaded programming and blocks.
- Web developer with some experience in core technologies, such as, HTML5, CSS3, XML, JSON, WebGL, PHP, d3.js, Node.js and MongoDB.
- Remote versioning systems, such as GIT.

Most recent publications (submitted or published)

Complex systems: features, similarity and connectivity

C. H. Comin, T. Peron, F. N. Silva, D. R. Amancio, F. A. Rodrigues, L. da F Costa
Physics Reports, 2020

DOI: [10.1016/j.physrep.2020.03.002](https://doi.org/10.1016/j.physrep.2020.03.002)

Role: all authors contributed equally to this work

How are scientific works viewed?

A. C. M. Brito, F. N. Silva, H. F. de Arruda, C. H. Comin, D. R. Amancio, L. da F Costa
arXiv preprint arXiv:2005.04512, 2020

<https://arxiv.org/abs/2005.04512>

Submitted to Journal of Informetrics

Role: Conceptualization, data, analysis, methodology, writing – review & editing

A complex network approach to political analysis: Application to the Brazilian Chamber of Deputies

A. C. M. Brito, F. N. Silva, D. R. Amancio

Plos one, v. 15, n. 3, p. e0229928, 2020

DOI: [10.1371/journal.pone.0229928](https://doi.org/10.1371/journal.pone.0229928)

Role: Conceptualization, data, analysis, methodology, writing – review & editing

Opinion diversity and social bubbles in adaptive Sznajd networks

A. Benatti, H. F. de Arruda, F. N. Silva, C. H. Comin, L. da F. Costa

Journal of Statistical Mechanics: Theory and Experiment, v. 2020, n. 2, p. 023407, 2020

DOI: [10.1088/1742-5468/ab6de3](https://doi.org/10.1088/1742-5468/ab6de3)

Role: Conceptualization, methodology, writing – review & editing

Recency predicts bursts in the evolution of author citations

F. N. Silva, A. Tandon, D. R. Amancio, A. Flammini, F. Menczer, S. Milojević, S.

Fortunato

arXiv preprint arXiv:1911.11926, 2019

<https://arxiv.org/abs/1911.11926>

Accepted in Quantitative Science Studies

Role: Conceptualization, data, analysis, methodology, writing – review & editing

Contrarian effects and echo chamber formation in opinion dynamics

H. F. de Arruda, A. Benatti, F. N. Silva, C. H. Comin, L. da F. Costa

arXiv preprint arXiv:1910.06487, 2019

<https://arxiv.org/abs/1910.06487>

Submitted to JSTAT

Role: Conceptualization, methodology, writing – review & editing

Most recent activities

FUNDED PROJECTS 20% FTE (grant NIH/1R01EB029272-01) for designing network neuroscience brainlife apps.

20% FTE (AFOSR/FA9550-19-1-0391) for contributing to the science genome project.

GRANT PROPOSAL *Inequality in Collaboration and Mobility Dynamics of Researchers in the U.S.* Submitted to Facebook call: *Economic Opportunity and Digital Platforms request for proposals* (not funded)

OPEN SOURCE Brainlife Network Neuroscience Apps

SOFTWARE Basic set of apps to process and analyze networks derived from brain data.

<https://doi.org/10.25663/brainlife.app.289>

<https://doi.org/10.25663/brainlife.app.277>

<https://doi.org/10.25663/brainlife.app.290>

<https://doi.org/10.25663/brainlife.app.321>

<https://doi.org/10.25663/brainlife.app.306>

Helios Core

Core component of the Helios project. Implements a parallelized force-directed layout algorithm.

<https://github.com/heliosnet/helios-core>

CVRandomWalks

Fast implementation of random walks to be used as input for node embedding methods.

<https://github.com/filipinascimento/>

[CVRandomWalks](#)

WORKSHOPS AND CONFERENCES Designed and presented part of the tutorial for the CADRE project at the ISSI 2019 conference.

<https://github.com/iuni-cadre/ISSI-tutorial>

Abstracts for works *Modeling bursts in the evolution of author citations* and *The Brazilian Chamber of Deputies as a complex network* were accepted for IC2S2 2020.

All publications

Malleability of complex networks

Filipi N. Silva, Cesar H. Comin, Luciano da F. Costa

Journal of Statistical Mechanics: Theory and Experiment, v. 2019, n. 8, p. 083203, 2019

<https://arxiv.org/abs/1810.09602>

DOI: [10.1088/1742-5468/ab2ad1](https://doi.org/10.1088/1742-5468/ab2ad1)

Connecting Network Science and Information Theory

H. F. de Arruda, F. N. Silva, C. H. Comin, D. R. Amancio, L. da F. Costa

Physica A: Statistical Mechanics and its Applications, v. 515, n. 1, p. 641–648, 2019

<https://arxiv.org/abs/1704.03091>

DOI: [10.1016/j.physa.2018.10.005](https://doi.org/10.1016/j.physa.2018.10.005)

Dynamic Gene Network Analysis of Caco-2 Cell Response to Shiga Toxin-Producing Escherichia coli-Associated Hemolytic-Uremic Syndrome

Silvia Y Bando, Priscila Iamashita, Filipi N Silva, Luciano da F Costa, Cecilia M Abe,

Fernanda B Bertonha, Beatriz EC Guth, André Fujita, Carlos A Moreira-Filho

Microorganisms, v. 7, n. 7, p. 195, 2019

<https://pubmed.ncbi.nlm.nih.gov/31288487/>

DOI: [10.3390/microorganisms7070195](https://doi.org/10.3390/microorganisms7070195)

Visualizing Complex Networks (CDT-5)

Filipi N Silva, Luciano da Fontoura Costa

ResearchGate, 2018

<https://www.researchgate.net/publication/>

328811693 Visualizing Complex Networks CDT-5

DOI: [10.13140/RG.2.2.21310.74567/1](https://doi.org/10.13140/RG.2.2.21310.74567/1)

Can Spatiality Promote Diversity?

B. Messias, F. N Silva, C. H Comin, L. da F. Costa

arXiv preprint arXiv:1809.00729, 2018

<https://arxiv.org/abs/1802.09337>

The Dynamics of Knowledge Acquisition via Self-Learning in Complex Networks

T. S Lima, H. F de Arruda, F. N Silva, C. H Comin, D. R Amancio, L. da F. Costa

Chaos: An Interdisciplinary Journal of Nonlinear Science, v. 28, n. 8, 2018

<https://arxiv.org/abs/1802.09337>

doi: doi.org/10.1063/1.5027007

All publications (cont)

Topological characterization of world cities

G. S. Domingues, F. N. Silva, C. H. Comin, L. da F. Costa

Journal of Statistical Mechanics: Theory and Experiment, v. 2018, n. 8, p. 083212, 2018

<https://arxiv.org/abs/1709.08244>

doi: [10.1088/1742-5468/aad365](https://doi.org/10.1088/1742-5468/aad365)

A pattern recognition approach to transistor array parameter variance

L. da F. Costa, F. N. Silva, C. H. Comin

Physica A: Statistical Mechanics and its Applications, v. 499, p. 176--185, 2018

<http://arxiv.org/abs/1708.00469>

doi: [10.1016/j.physa.2018.10.005](https://doi.org/10.1016/j.physa.2018.10.005)

Characterizing BJTs using the Early voltage in the forward active mode

L. da F. Costa, F. N. Silva, Cesar H. Comin

International Journal of Circuit Theory and Applications, v. 46, n. 4, p. 978--986, 2018

<https://arxiv.org/abs/1701.02269>

doi: [10.1002/cta.2450](https://doi.org/10.1002/cta.2450)

Representation of texts as complex networks: a mesoscopic approach

H. F. de Arruda, F. N. Silva, V. Q. Marinho, D. R. Amancio, L. da F. Costa

Journal of Complex Networks, p. cnx023, 2017

<https://arxiv.org/abs/1606.09636>

doi: [10.1093/comnet/cnx023](https://doi.org/10.1093/comnet/cnx023)

Knowledge Acquisition: A Complex Networks Approach

H. F. de Arruda, F. N. Silva, L. da F. Costa, D. R. Amancio

Information Sciences, 2017

<https://arxiv.org/abs/1703.03366>

doi: [10.1016/j.ins.2017.08.091](https://doi.org/10.1016/j.ins.2017.08.091)

Patterns of authors contribution in scientific manuscripts

E. A. Corrêa Jr, F. N. Silva, L. da F. Costa, D. R. Amancio

Journal of Informetrics, v. 11, n. 2, p. 498--510, 2017

<https://arxiv.org/abs/1609.05545>

doi: [10.1016/j.joi.2017.03.003](https://doi.org/10.1016/j.joi.2017.03.003)

Uso de Ferramentas de Visualização de Dados Científicos em Ensino Interdisciplinar

F. N. Silva, L. da F. Costa

PRÓ-REITORIA DE GRADUAÇÃO, 2016

http://www.prg.usp.br/wp-content/uploads/anais_congresso_graduacao_usp_2016_v2.pdf

All publications (cont)

Using network science and text analytics to produce surveys in a scientific topic

F. N. Silva, D. R. Amancio, M. Bardosova, L. da F. Costa, O. N. Oliveira Jr.

Journal of Informetrics, v. 10, n. 2, p. 487--502, 2016

<https://arxiv.org/abs/1506.05690>

doi: [10.1016/j.joi.2016.03.008](https://doi.org/10.1016/j.joi.2016.03.008)

Seeking maximum linearity of transfer functions

F. N. Silva, C. H. Comin, L. da F. Costa

Review of Scientific Instruments, v. 87, n. 12, p. 124701, 2016

<https://arxiv.org/abs/1608.04008>

doi: [10.1063/1.4969058](https://doi.org/10.1063/1.4969058)

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