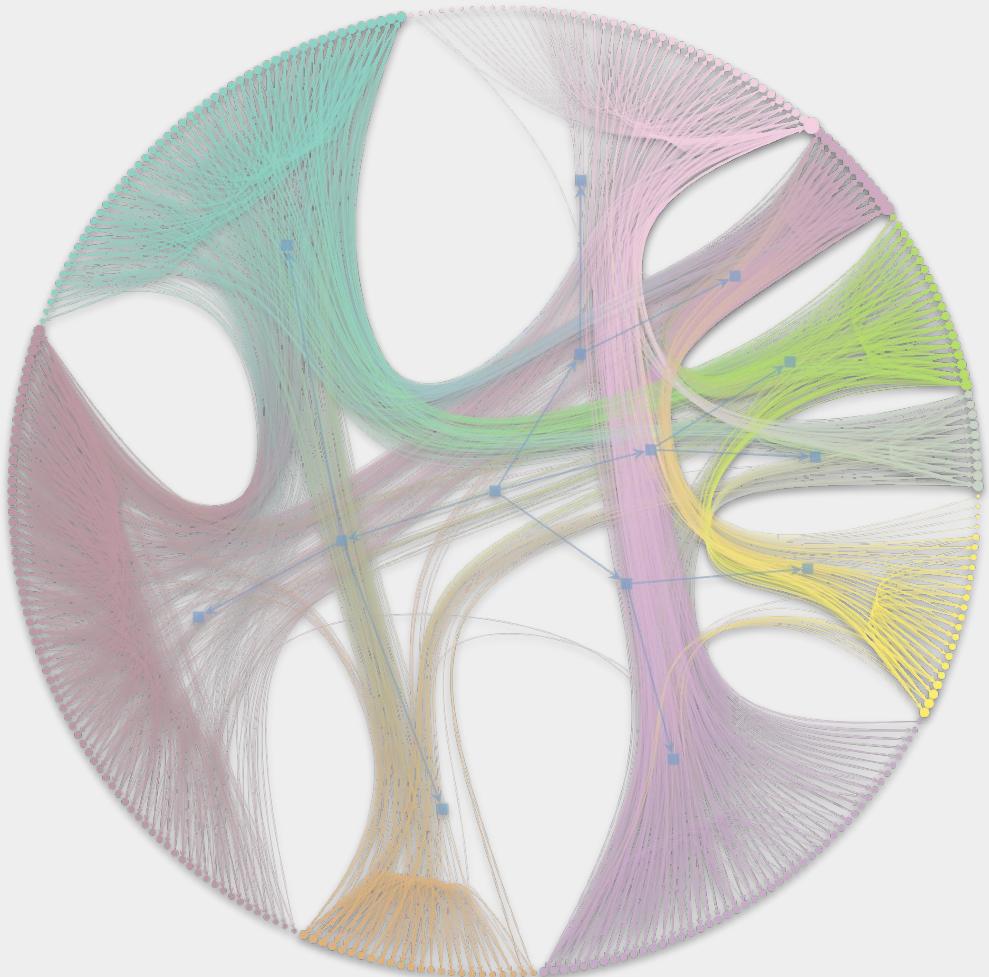


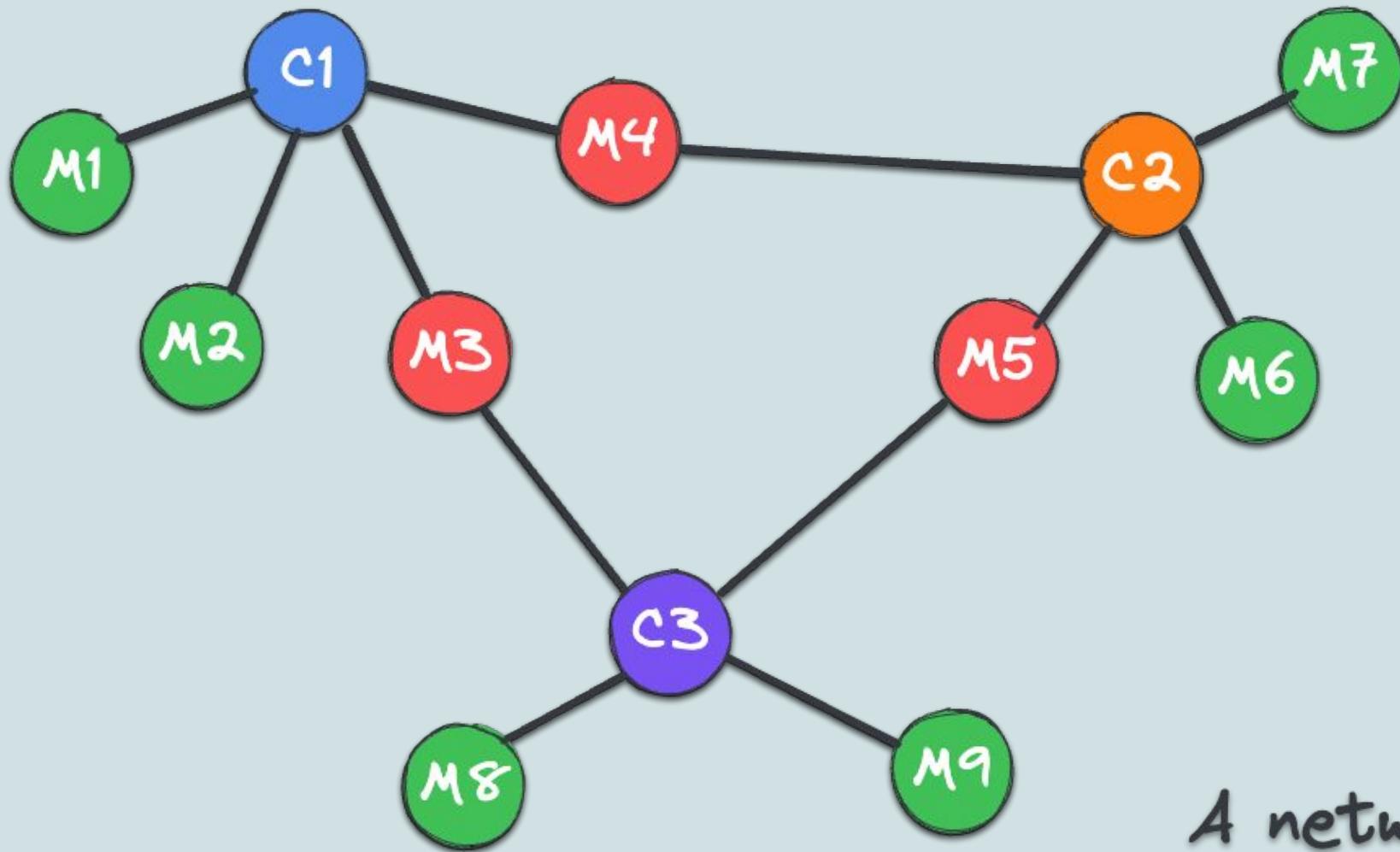
# Network Elements

## Part 01

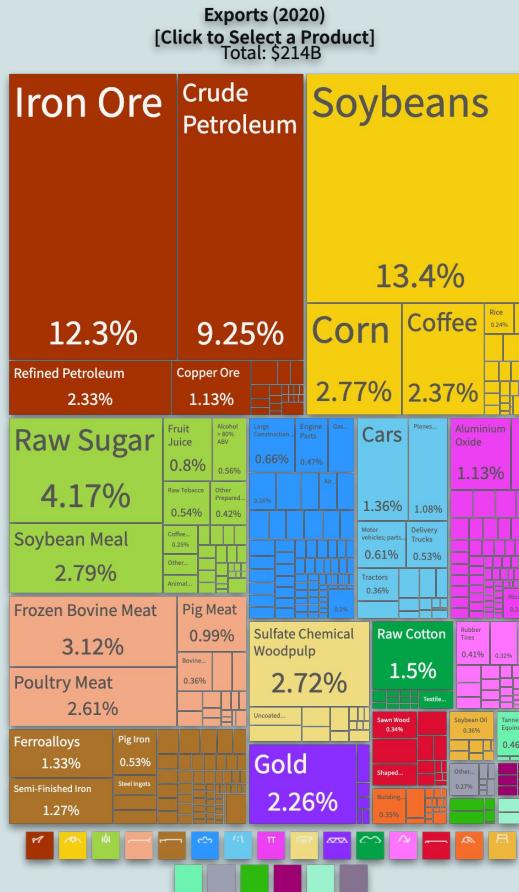
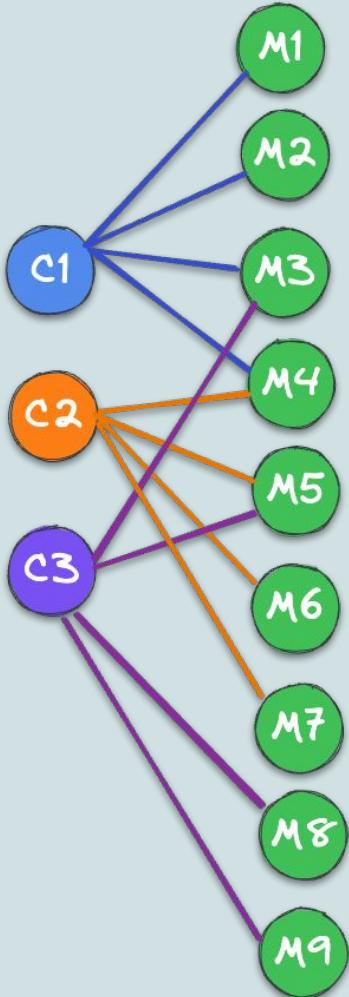
ivanovitch.silva@ufrn.br  
@ivanovitchm



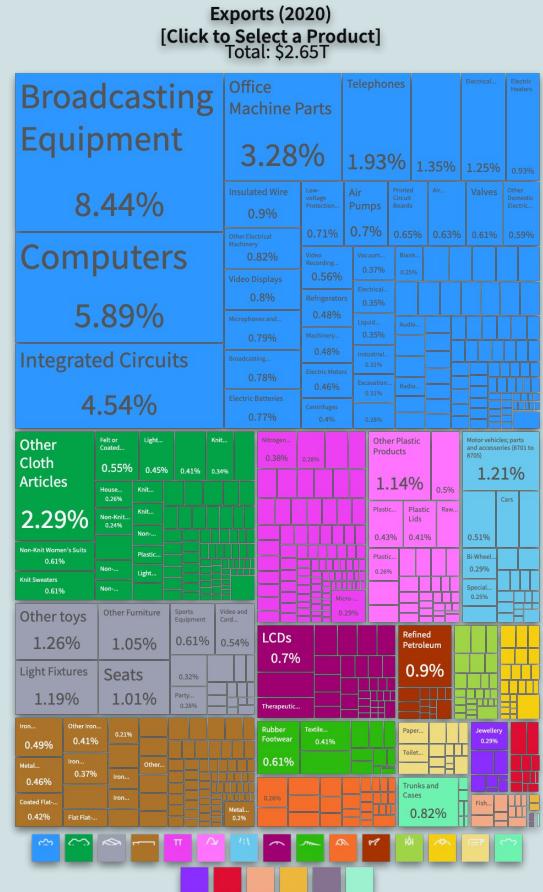




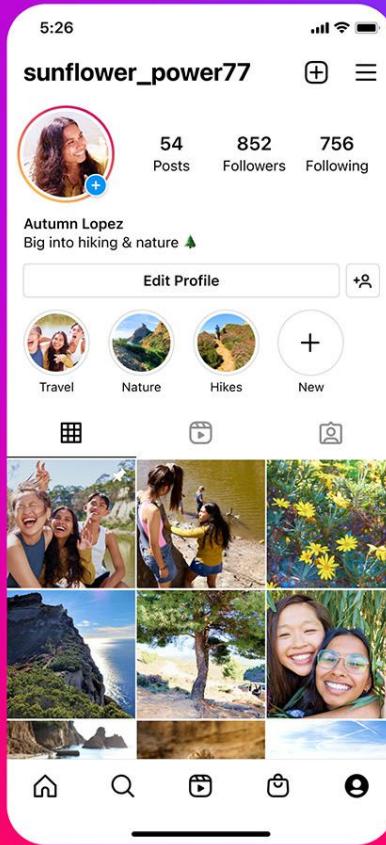
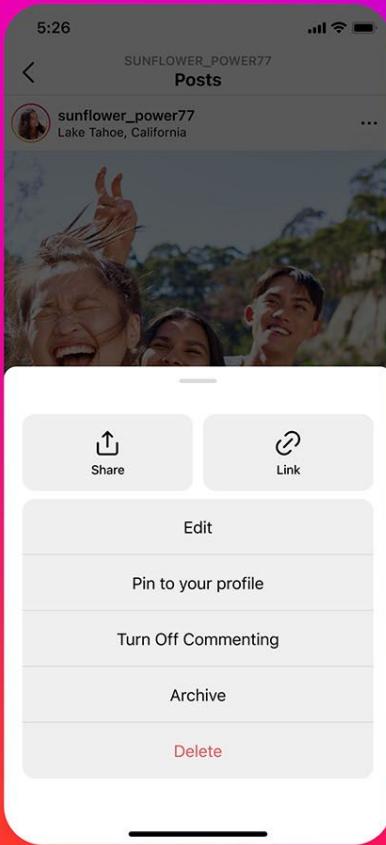
*A network*

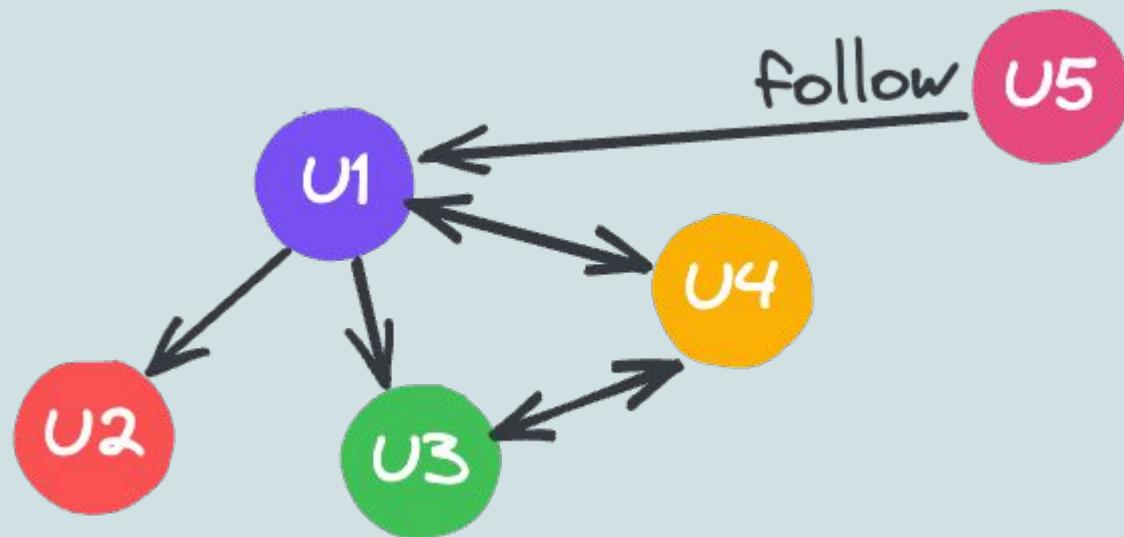


bipartite network



<https://oec.world/en/profile/country/chn>





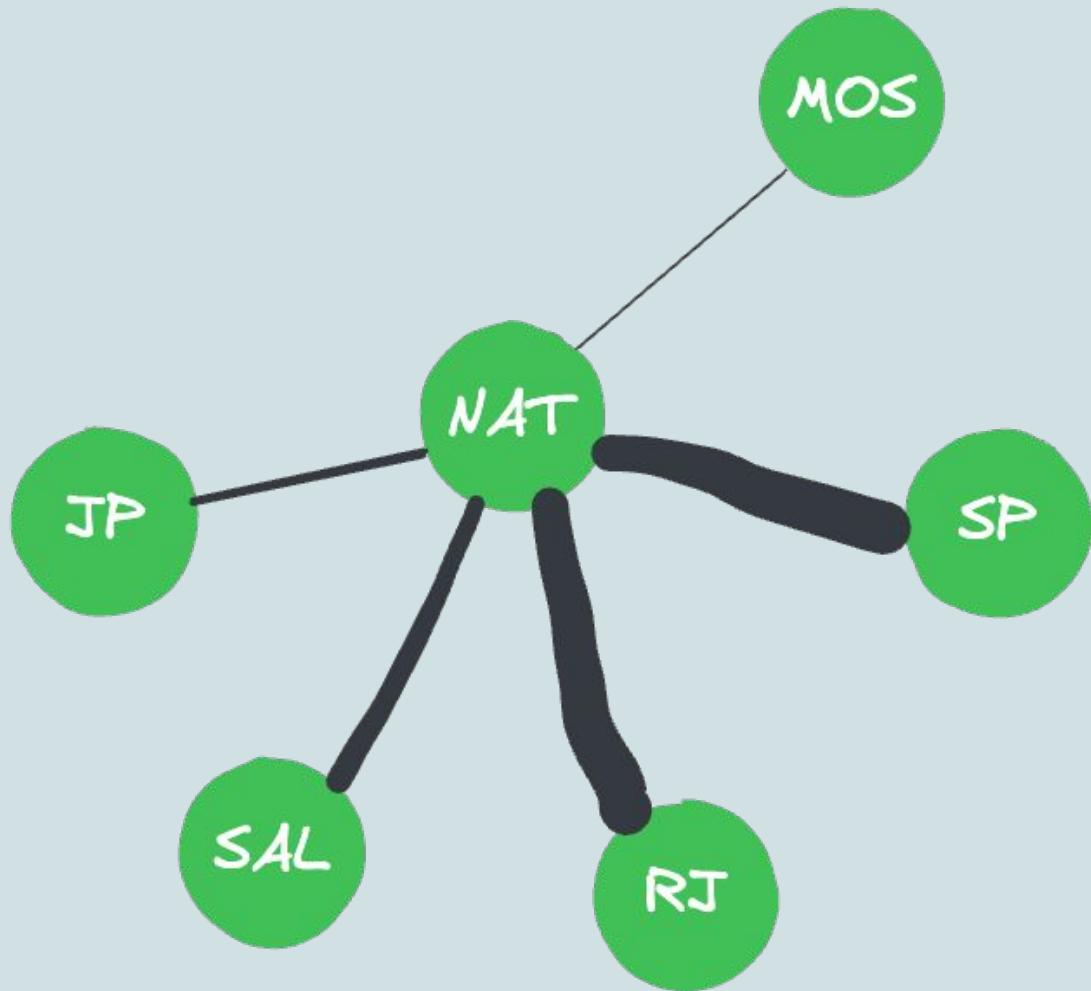
leomessi ✅ Following Message +299 ...

1,102 posts 488M followers 299 following

Leo Messi  
Athlete  
Bienvenidos a la cuenta oficial de Instagram de Leo Messi / Welcome to the official Leo Messi Instagram account  
[apple.co/Messigift](http://apple.co/Messigift)

This image shows a screenshot of the Instagram profile for the account "leomessi". The profile picture is a family photo of Leo Messi and his wife Antonella Roccuzzo with their three children. The bio reads: "Bienvenidos a la cuenta oficial de Instagram de Leo Messi / Welcome to the official Leo Messi Instagram account". A link "apple.co/Messigift" is also present in the bio. The account has 1,102 posts, 488 million followers, and is following 299 accounts. The "Following" button is grayed out, indicating the user is already following the account.





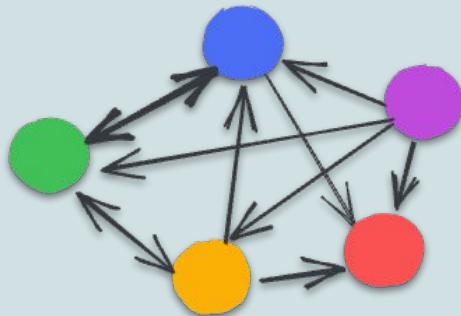


# WhatsApp

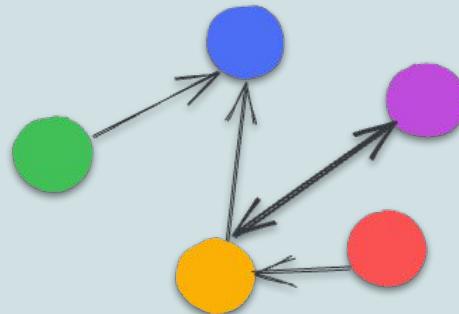


<https://github.com/kurasaitja/Whatsapp-Analysis>

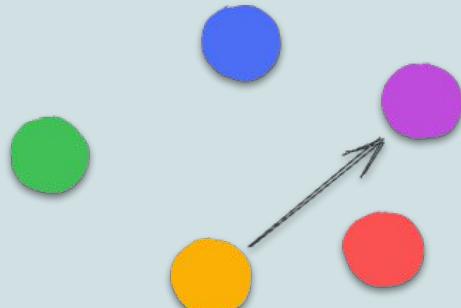
Monday



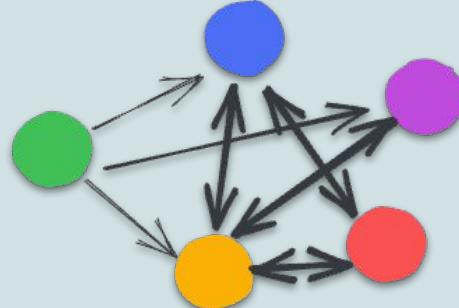
Tuesday



Wednesday



Thursday



Temporal network



# Jure Leskovec

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Professor of Computer Science, [Stanford University](#).  
Verified email at cs.stanford.edu - [Homepage](#)

Data mining Machine Learning Graph Neural Networks Knowledge Graphs Complex Networks

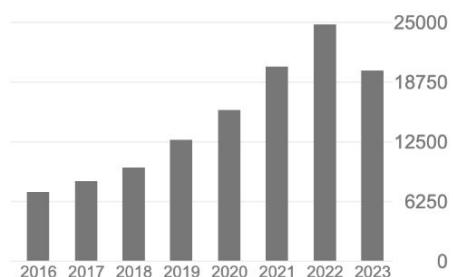
TITLE	CITED BY	YEAR
Inductive representation learning on large graphs W Hamilton, Z Ying, J Leskovec Advances in neural information processing systems 30	11796	2017
node2vec: Scalable feature learning for networks A Grover, J Leskovec Proceedings of the 22nd ACM SIGKDD international conference on Knowledge ...	10392	2016
How powerful are graph neural networks? K Xu, W Hu, J Leskovec, S Jegelka arXiv preprint arXiv:1810.00826	5536	2018
SNAP Datasets: Stanford large network dataset collection J Leskovec, A Krevl	4054	2014
Friendship and mobility: user movement in location-based social networks E Cho, SA Myers, J Leskovec Proceedings of the 17th ACM SIGKDD international conference on Knowledge ...	3468	2011
Graphs over time: densification laws, shrinking diameters and possible explanations J Leskovec, J Kleinberg, C Faloutsos Proceedings of the eleventh ACM SIGKDD international conference on Knowledge ...	3137	2005

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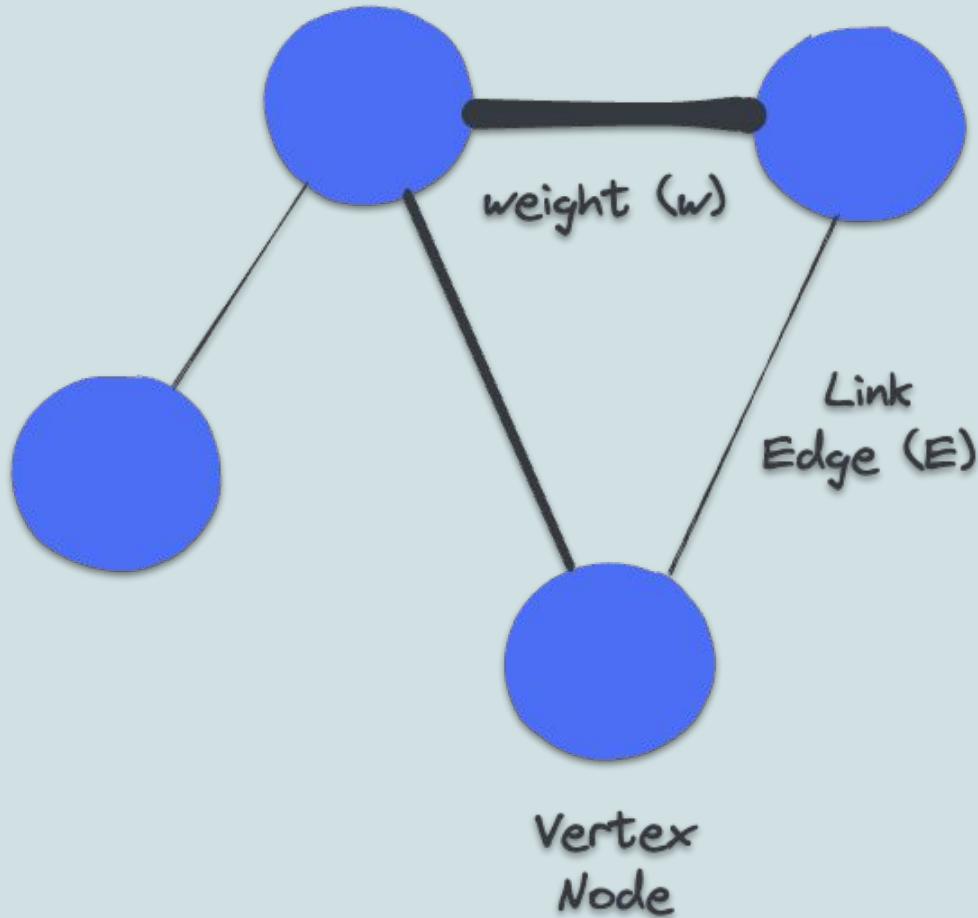
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## Co-authors



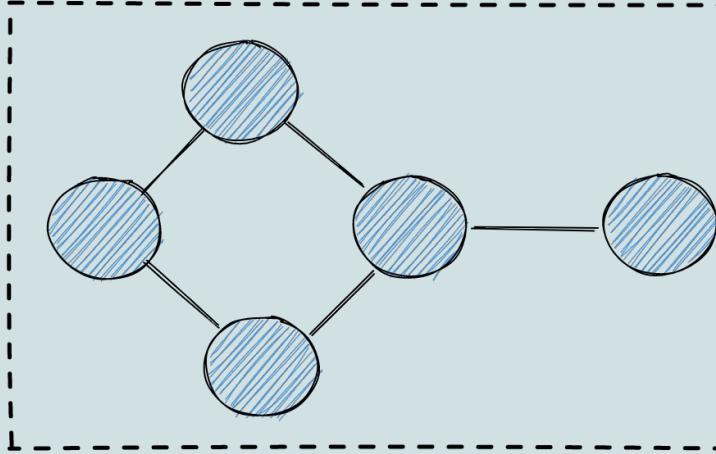
# Basic Definitions

$$G = (V, E, W)$$

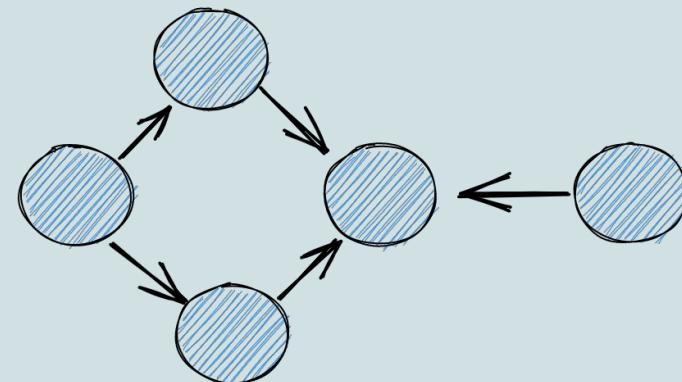
$$E \subseteq V \times V$$

$$W \subseteq R^+$$

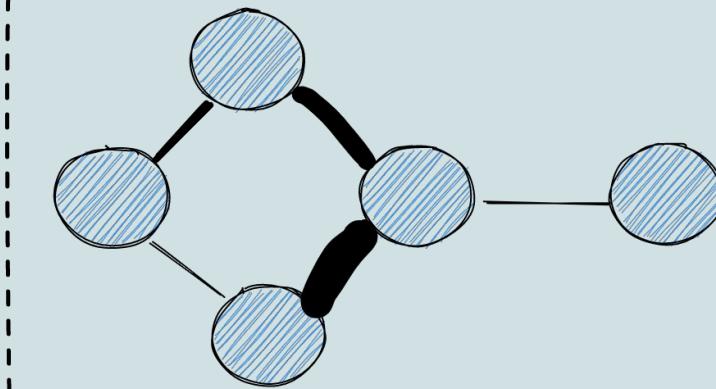
Undirected



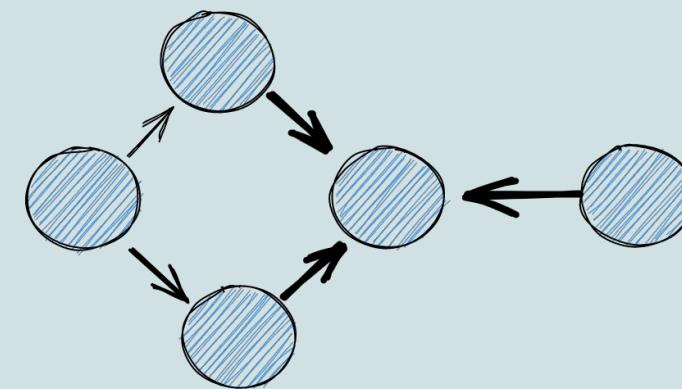
Directed



Unweighted



Weighted



## Knowing

Information is directly acquired from reliable sources such as books, teachers, lectures, and courses

Focus on absorbing and retaining information.

Learning that takes place when information or experiences are exchanged between individuals or groups.

Teaching others reinforces one's own understanding.

## Sharing

Learning

## Discovering

Self-directed learning that happens when one ventures out to find new information

Driven by curiosity and inherently exploratory.

"Learning by doing", based on the premise that direct experience is one of the most potent forms of learning.

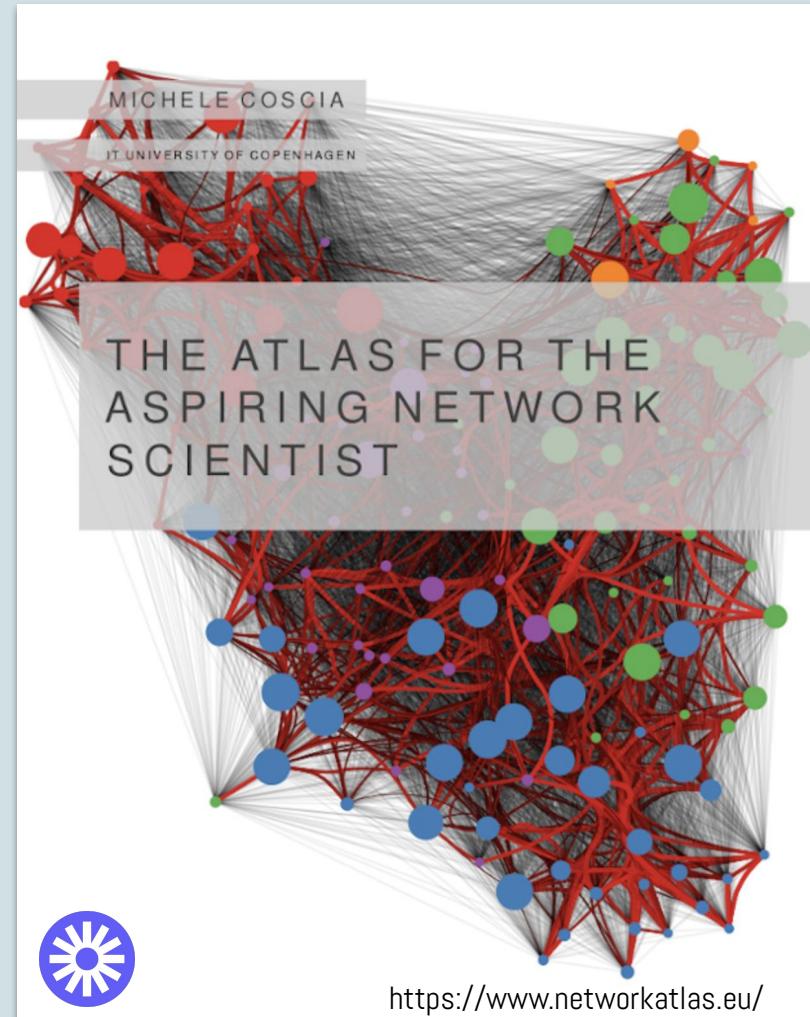
Involves real-life situations

## Experiencing

# Further Reading



1	<i>Introduction</i>	9
I	<i>Basics</i>	21
2	<i>Probability Theory</i>	22
3	<i>Basic Graphs</i>	40
4	<i>Extended Graphs</i>	48
5	<i>Matrices</i>	68
II	<i>Simple Properties</i>	89
6	<i>Degree</i>	90





## Contact

[Mailing list](#)

[Issue tracker](#)

[Source](#)

## Releases

[Stable \(notes\)](#)

3.1 — April 2023

[Documentation](#)

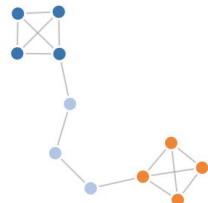
[Latest \(notes\)](#)

3.2 development

[Documentation](#)

[Archive](#)

NetworkX is a Python package for the creation, manipulation, and study of the structure, dynamics, and functions of complex networks.



## Software for complex networks

- Data structures for graphs, digraphs, and multigraphs
- Many standard graph algorithms
- Network structure and analysis measures
- Generators for classic graphs, random graphs, and synthetic networks
- Nodes can be "anything" (e.g., text, images, XML records)
- Edges can hold arbitrary data (e.g., weights, time-series)
- Open source [3-clause BSD license](#)
- Well tested with over 90% code coverage
- Additional benefits from Python include fast prototyping, easy to teach, and multi-platform

## What is graph-tool?

Graph-tool is an efficient [Python](#) module for manipulation and statistical analysis of [graphs](#) (a.k.a. [networks](#)). Contrary to most other Python modules with similar functionality, the core data structures and algorithms are implemented in [C++](#), making extensive use of [template metaprogramming](#), based heavily on the [Boost Graph Library](#). This confers it a level of [performance](#) that is comparable (both in memory usage and computation time) to that of a pure C/C++ library.

### ► It is *Fast!*

Despite its nice, soft outer appearance of a regular Python module, the core algorithms and data structures of graph-tool are written in C++, with performance in mind. Most of the time, you can expect the algorithms to run just as fast as if graph-tool were a pure C/C++ library. See a [performance comparison](#).

### ● OpenMP Support

Many algorithms are implemented in parallel using [OpenMP](#), which provides excellent performance on multi-core architectures, without degrading it on single-core machines.

### ● Extensive Features

An extensive array of features is included, such as support for arbitrary vertex, edge or graph [properties](#), efficient "on the fly" [filtering](#) of vertices and edges, powerful graph I/O using the [GraphML](#), [GML](#) and [dot](#) file formats, graph [pickling](#), [graph statistics](#) (degree/property histogram, vertex correlations, average shortest distance, etc.), [centrality measures](#), standard [topological algorithms](#) (isomorphism, minimum spanning tree, connected components, dominator tree, [maximum flow](#), etc.), [generation of random graphs](#) with arbitrary degrees and correlations, [detection of modules and communities](#) via statistical inference, and much more.

### ● Download version 2.58

[Installation instructions](#) | [Changelog](#)

Conda installation (GNU/Linux | MacOS)

```
conda create --name gt -c conda-forge graph-tool  
conda activate gt
```

◀ ▶



### ● Powerful Visualization

Conveniently [draw](#) your graphs, using a variety of algorithms and output formats (including to the screen). Graph-tool has its own layout algorithms and versatile, interactive drawing routines based on [cairo](#) and [GTK+](#), but it can also work as a very comfortable interface to the excellent [graphviz](#) package.

### ● Fully Documented

Every single function in the module is documented in the docstrings and in the online [documentation](#), which is full of examples.