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Network Diffusion — Framework to Simulate Spreading Processes in Complex Networks

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Agenda

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- 2 Key Features of `network-diffusion`
- 3 Example - Custom Model
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- 5 Limitations of `network-diffusion`

Motivation

Spreading phenomena are one of the problems considered by a network science. They can be observed in various areas like: dynamics of political opinions, marketing campaigns, spread of epidemics, computer viruses, etc.



Figure: Artistic representation of a social network.¹

¹Source: www.uniroma3.it/articoli/seminario-biased-opinion-dynamics-when-the-devil-is-in-the-details-138122

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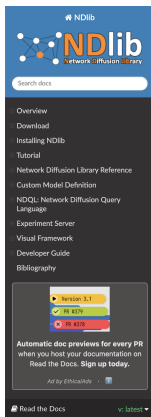


Thus, many tools were developed to address that issue, allow researchers to get rid of the need to start their experiments from scratch, and enhance the reproducibility of results.

Motivation

Here is a bunch of tools that help in simulating diffusion processes in networks:

- NDlib[5],
- GLEaMviz[2],
- SimInf[6],
- STEM[3],
- EpiModel[4],
- Sisspread[1],
- ...



Docs > NDlib - Network Diffusion Library

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NDlib - Network Diffusion Library

NDlib is a Python software package that allows to describe, simulate, and study diffusion processes on complex networks.

Date	Python Versions	Main Author	GitHub	pypl
2023-09-08	>=3.6	Giulio Rossetti	Source	Distribution

If you use NDlib as support to your research consider citing:

G. Rossetti, L. Milli, S. Rinzivillo, A. Sirbu, D. Pedreschi, F. Giannotti. "NDlib: a Python Library to Model and Analyze Diffusion Processes Over Complex Networks" Journal of Data Science and Analytics. 2017. DOI:10.1007/s41060-017-0086-6 (pre-print available on [arXiv](#))

G. Rossetti, L. Milli, S. Rinzivillo, A. Sirbu, D. Pedreschi, F. Giannotti. "NDlib: Studying Network Diffusion Dynamics" IEEE International Conference on Data Science and Advanced Analytics, DSAA, 2017.

NDlib Dev Team

Name	Contribution
Giulio Rossetti	Library Design/Documentation
Leticia Milli	Epidemic Models
Alina Sirbu	Opinion Dynamics Model
Salvatore Rinzivillo	Visual Platform
Mathijs Majer	Continuous Model

Figure: NDlib's website.

However, if we consider more complex...

...network models (e.g. multilayer graphs)...

...diffusion models (e.g. spreading of coexisting processes)...

...a gap among the available toolkits emerges.

Motivation

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With regard to the observed gap, we decided to merge and wrap the code into a library to share it with the community as a small contribution to make experiments easier.

Key Features of `network-diffusion`

Functionalities of the library:

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- end-to-end workflow for simulations of spreading phenomena,
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- an interface for implementing custom discrete spreading models,
- support for temporal networks (CogSNet and snapshot-based),
- support for the multilayer networks,
- most of centrality metrics extended to multilayer networks.

Key Features of `network-diffusion`

Environmental requirements/features:

- released under MIT licence,
- support for Linux, macOS, and Windows²,
- Python ≥ 3.10 compatibility,
- C snippets in the CogSNet module to speed-up computations,
- NetworkX compatibility.

²Although we develop and use it mostly on Unix OSs

Example - Custom Model

In this example we will consider a joint disease-awareness model (SIR-UA) that can be used e.g. to assess the effectiveness of various countermeasures against the spread of COVID-19:

Table: Transition weights with explanation.

Symbol	Description
α	probability of infection for unaware agents
α'	probability of infection for aware agents
β	probability of recovery
γ	probability of awareness for uninfected agents
δ	probability of awareness for infected agents

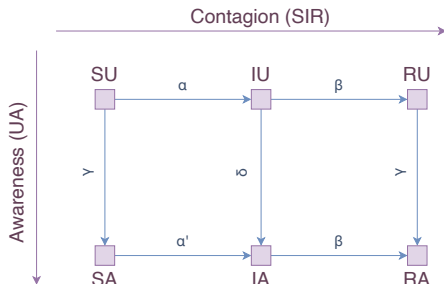


Figure: State and transition graph for SIR-UA.

Example - Custom Model

To create an own spreading model, we have to extend the abstract base class (`nd.models.BaseModel`) by implementing:

- a field `_compartmental_graph`,
- a field `_seed_selector`,
- a method `determine_initial_states`,
- a method `agent_evaluation_step`,
- a method `network_evaluation_step`,
- methods `__str__` and `get_allowed_states`.

The following entities (with implemented method `update_network`) are utilised in the class `nd.Simulator` which orchestrates the experiment.

Example - Custom Model

Let's model this problem with `network-diffusion`!

The library can be installed with:

```
pip install network-diffusion
```

We have also published other useful resources:

- PyPI website: pypi.org/project/network-diffusion,
- GitHub page: github.com/anty-filidor/network_diffusion,
- Reference guide: network-diffusion.readthedocs.io,
- Paper with more use-cases presented: arxiv.org/abs/2405.18085.

There is still some work to do...

- computational performance can be better,
- we are limited to discrete spreading models,
- we cannot model agent's complex states (e.g. internal/external),
- much less predefined spreading models than in NDlib,
- library maintenance guaranteed up to my graduation 😊.

- [1] Fabian Alvarez et al. “Sispread: A Software to Simulate Infectious Diseases Spreading on Contact Networks”. In: Methods of information in medicine 46 (2007), p. 19. DOI: [10.1055/s-0038-1627827](https://doi.org/10.1055/s-0038-1627827). URL: <https://doi.org/10.1055/s-0038-1627827>.
- [2] Wouter Van den Broeck et al. “The GLEaMviz Computational Tool, a Publicly Available Software to Explore Realistic Epidemic Spreading Scenarios at the Global Scale”. In: BMC Infectious Diseases 11.1 (Feb. 2011), p. 37. ISSN: 1471-2334. DOI: [10.1186/1471-2334-11-37](https://doi.org/10.1186/1471-2334-11-37). URL: <https://doi.org/10.1186/1471-2334-11-37>.
- [3] Judith Douglas et al. “STEM: An Open Source Tool for Disease Modeling”. In: Health security (Aug. 2019). DOI: [10.1089/hs.2019.0018](https://doi.org/10.1089/hs.2019.0018). URL: <https://doi.org/10.1089/hs.2019.0018>.

- [4] Samuel M Jenness, Steven M Goodreau, and Martina Morris. “EpiModel: an R package for mathematical modeling of infectious disease over networks”. In: Journal of statistical software 84 (2018). DOI: [10.18637/jss.v084.i08](https://doi.org/10.18637/jss.v084.i08). URL: <https://doi.org/10.18637/jss.v084.i08>.
- [5] Giulio Rossetti et al. “NDlib: A Python Library to Model and Analyze Diffusion Processes Over Complex Networks”. In: Int. J. Data Sci. Anal. 5.1 (Feb. 2018), pp. 61–79. ISSN: 2364-4168. DOI: [10.1007/s41060-017-0086-6](https://doi.org/10.1007/s41060-017-0086-6). URL: <https://doi.org/10.1007/s41060-017-0086-6>.
- [6] Stefan Widgren et al. “SimInf: An R Package for Data-Driven Stochastic Disease Spread Simulations”. In: Journal of Statistical Software 91.12 (2019), pp. 1–42. DOI: [10.18637/jss.v091.i12](https://doi.org/10.18637/jss.v091.i12). URL: <https://doi.org/10.18637/jss.v091.i12>.

Thank you for your attention!



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