Complex Networks: Theory, Methods, and Applications

Lake Como School of Advanced Studies - 22-26 May 2023

Home

Complex networks: Theory, Methods, and Applications (7th edition)
Villa del Grumello, Como, Italy, May 22-26, 2023

Many real systems can be modeled as networks, where the elements of the system are nodes and interactions between elements are edges. An even larger set of systems can be modeled using **dynamical processes on networks**, which are in turn affected by the dynamics. Networks thus represent the backbone of many **complex systems**, and their theoretical and computational analysis makes it possible to gain insights into numerous applications. **Networks permeate almost every conceivable discipline** —including sociology, transportation, economics and finance, biology, and myriad others — and the study of "network science" has thus become a crucial component of modern scientific education.

The school "**Complex Networks: Theory, Methods, and Applications**" offers a succinct education in network science. It is open to all aspiring scholars in any area of science or engineering who wish to study networks of any kind (whether theoretical or applied), and it is especially addressed to **doctoral students** and **young postdoctoral scholars**. The aim of the school is to deepen into both theoretical developments and applications in targeted fields.

This is the **7th edition** of the school: click here to visit the website of the **6th edition** (2022).

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Italian Society for
Chaos and Complexity
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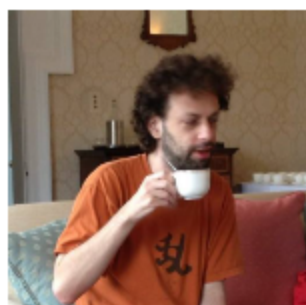**Yamir Moreno**
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Program

(last updated February 7, 2023)

[time zone UTC+2 – check your time lag at https://www.timeanddate.com/time/zone/italy]

Monday, 22 May, morning (9.30-12.30)
Introduction to complex networks with reflections on the first quarter century of a field (Dodds):   I will give what can only be a partial survey of the now massive field of (real) complex networks. I will first define and outline some basic meaningful properties of complex networks. I will chart the pre-history and paths of the founding and long-influential late-1990s papers on small-world networks and scale-free networks, locating them in larger academic endeavors.

From there, I'll touch on many topics of the structure and dynamics of real complex networks including: Conditions for networks to exist in the first place, and how complex networks are a subset of complex systems; Optimal distribution and redistribution networks; Structure detection and the universality of pyramid schemes; Random bipartite networks and groups; Generating function techniques, their beauty and their limitations; Models of biological and social contagion on networks; and Why pandemics are so unpredictable.

I will address some controversial areas in branching networks (rivers and cardiovascular) and scale-free networks. I will explain why the longstanding field of graph theory did not anticipate the field of complex networks (words versus stories, time, becoming). Throughout, I will aim to give historical backgrounds, as well as emphasize several principles. The advent of the internet and easily shared large-scale datasets has marked a new era of science, and it's why we have a field of complex networks. As such, keep measuring and examining the world. Do not force old network models on to new networks. Where possible, work towards the basic scientific goal of explicating mechanisms driving the generation of complex network phenomena. And for many problems that might seem to be simply networks, always consider the role and power of groups.

Expansions of the above and further material can be found in over a year's worth of slides and videos in my two-semester course on Principles of Complex Systems: https://pdodds.w3.uvm.edu/teaching/courses/2022-2023pocsverse

Monday, 22 May, afternoon (14.30-17.30)
Network motifs (Stegehuis):   Network motifs, or subgraphs, can be seen as the building blocks of complex networks. In this lecture, we will investigate how models for complex networks help us extract knowledge from these subgraphs. In particular, I will focus on the use of optimization problems, comparing with real-world network data and new challenges in higher-order networks.

Tuesday, 23 May, morning (9.30-12.30)
Allotaxonometry, Ousiometrics, and Telegnomics — Measurement of complex systems, essential meaning, and stories (Dodds):
Part 1. Allotaxonometry: The science and art of comparing complex systems.
Complex systems often comprise many kinds of components (types) which vary over many orders of magnitude in some kind of 'size': Populations of cities in countries, individual and corporate wealth in economies, species abundance in ecologies, word frequency in natural language, and node degree in complex networks.

I'll outline 'allotaxonometry' along with 'rank-turbulence divergence' (RTD), a tunable instrument for comparing any two (Zipfian) ranked lists of components, as well as a related-but-different instrument in 'probability-turbulence divergence' (PTD). I'll argue that RTD enables a most general comparison, as we need only ranks of components, and the ubiquitous use of rankings makes RTD powerfully interpretable.

I will motivate and outline the analytic development of rank-turbulence divergence. I will then explain a rank-based 'allotaxonograph' which pairs a map-like histogram for rank-rank pairs with an ordered list of components according to divergence contribution. We then build allotaxonographs to display RTD and PTD, incorporating for the latter a way to visually accommodate zero probabilities for 'exclusive types' which are types that appear in only one system. Allotaxonographs show how our divergences are instruments of a general machinery of type (or lexical) calculus.

I'll go over the performances of RTD and PTD for a series of distinct settings including: Language use on Twitter and in books, species abundance in ecology, baby name popularity, market capitalization, performance in sports, mortality causes, and job titles. I'll also show how probability-turbulence divergence either explicitly or functionally generalizes many existing kinds of distances.
Part 2. Ousiometrics and Telegnomics: The distant and computational measurement of essential meaning, history, and stories.
We define 'ousiometrics' to be the study of essential meaning in whatever context that meaningful signals are communicated, and 'telegnomics' as the study of remotely sensed knowledge. By re-examining first types and then tokens for the English language, and through the use of automatically annotated histograms — 'ousiograms'— we uncover that:
1. The essence of meaning conveyed by words is instead best described by a compass-like plane with major axes of powerful-weak and dangerous-safe;
2. Analysis of a disparate collection of large-scale English language corpora — literature, news, Wikipedia, talk radio, and social media — shows that natural language exhibits a systematic bias toward safe, low danger words — a reinterpretation of the Pollyanna principle's positivity bias for written expression.
I will connect these findings to our longstanding hedonometer project which we will also briefly explore. Happiness = Safety + Power.
I will outline our prototype 'ousiometer', a telegnomic instrument that measures ousiometric time series for temporal corpora.
I will show that the power-danger (PD) framework appears in other disparate venues including the distribution of character types in stories, discuss ousiometrics versus information entropy, and indicate an array of possible future work.
I will also touch on several kinds of distant story measurement including: dynamics of raw fame; computational historical timeline reconstruction; collective chronopathy, how time flies and crawls; and the ascent of K-Pop.
Related online instruments, visualizations, and exploratoria:
http://compstorylab.org/allotaxonometry
https://hedonometer.org
https://storylab.w3.uvm.edu/ousiometrics
https://storywrangling.org
http://compstorylab.org/trumpstoryturbulence/
http://compstorylab.org

Tuesday, 23 May, afternoon
no lectures

Wednesday, 24 May, morning (9.30-12.30)
Spreading dynamics I (Priesemann):   Spreading dynamics is ubiquitous: activity spreads in neural networks, news and fake news in social networks, and just recently the spread of a novel virus has disrupted the daily lives of people around the globe. We will first introduce two basic, complementary frameworks that describe such spreading dynamics: Stochastic processes, e.g. branching processes can capture the characteristic exponential growth and can account for the high variability. For large populations, a mean-field description via compartmental models can become very useful. We then show how these approaches help us to understand the "mechanics " of pandemic spread and mitigation. In the last part, we focus on the key feature of all these living networks, i.e. that the connections between neurons or interactions between agents are not static, but change systematically over time. In neural networks, this is essential to implement learning, for the pandemic it was key to mitigating the spread of SARS-CoV-2. We derive the principles of self-organization in these diverse networks, show under which conditions phase transitions and critical phenomena occur, and how these can help to optimize information flow.

Wednesday, 24 May, afternoon (14.30-17.30)
Spreading dynamics II (Bansal):   Mathematical models of infectious disease dynamics typically focus on relationships between aggregated state variables while smoothing over individual-level variability. But approaches of network epidemiology that incorporate individual heterogeneity in transmission have made important contributions to public health. We will (a) derive some fundamental theoretical models of spreading dynamics on networks that allow for modeling heterogeneity and targeting interventions; (b) review how network modeling approaches have helped develop an understanding of the relationship between structure and function; and (c) discuss some applied case studies including the use of network approaches to identify super-spreading individuals in the transmission of pathogens such as SARS and H1N1 influenza, quantify transmission risk for pathogens such as HIV and gonorrhea, and intervention design for pathogens in livestock systems.

Wednesday, 24 May, evening (20.00)
social dinner

Thursday, 25 May, morning (9.30-12.30)
short talks by students

Thursday, 25 May, afternoon
no lectures

Friday, 26 May, morning (9.30-12.30)
Inter-industry labour flow networks (O'Clery):   There is an emerging consensus in the economic development literature that locally embedded capabilities and industrial know-how are key determinants of growth and diversification processes. In order to model these dynamics as a branching process, whereby industries grow as a function of the availability of related or relevant skills, inter-industry labour flow networks are typically employed. Existing models, however, typically deploy a local or 'nearest neighbour' approach to capture the size of the labour pool available to an industry in related sectors. This approach, however, ignores higher order interactions in the network, and the presence of industry clusters or groups of industries which exhibit high internal skill overlap. We argue that these clusters represent skill basins in which workers circulate and diffuse knowledge, and delineate the size of the skilled labour force available to an industry. In a first study, we combine multi-scale community detection with an econometric model to uncover the optimal scale at which labour pooling operates. In a second study, we investigate the extent to which these networks differ in community structure across countries by developing a new bi-directional method to compare the modular structure of a pair of node-aligned networks.

Friday 26 May, afternoon (14.30-17.30)
Urban complex systems (Arcaute):   In this lecture we will look at urban systems from the perspective of complexity science. Some of the characteristics that these systems present are emergent spatial patterns, such fractals among others. These can be derived from physical but also social and economic phenomena. Within this lecture, we will review some of the fundamental aspects and frameworks of urban complexity science. In particular, we will construct different types of spatial networks that will help us identify different characteristics, such as the hierarchical organisation of regions and countries, and the observed heterogeneities and inequalities in the functioning of cities. We will look at different transport networks and their flows, and introduce relevant measures, such as accessibility. We will also construct networks representing proxies for interaction between areas or communities that will help us identify the above-mentioned spatial patterns.

Lecturers

Elsa Arcaute
University College London
www.ucl.ac.uk/bartlett/casa/dr-elsa-arcaute

Shweta Bansal
Georgetown University
sbansal.com

Peter Dodds
University of Vermont
www.uvm.edu/cems/mathstat/profiles/peter_dodds

Neave O'Clery
University College London
neaveoclery.com

Viola Priesemann
Max Planck Institute for Dynamics and Self-Organization
www.viola-priesemann.de

Clara Stegehuis
Twente University
www.clarastegehuis.nl

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Contacts

For enquiries about the **scientific aspects of the school**, please contact Carlo Piccardi (carlo.piccardi@polimi.it) or any other member of the Organizing Committee.

For enquiries about the **venue** of the school, **travel**, **accommodation**, and **application** procedure, please contact Alessandra Cazzaniga (alessandra.cazzaniga@fondazionealessandrovolta.it) at Fondazione Alessandro Volta, Como.

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Application

To ensure distancing, only **a limited number of qualified and selected students will be admitted ONSITE**; other students will be allowed to attend the school **ONLINE** (Zoom platform).

In compliance with the regulation currently in force, the school will be open to

- **45 students onsite**. Registration fee: **500 euro** (VAT 22% included). The fee covers: all lectures; course material; wi-fi connections; lunches and coffee breaks; social dinner. The fee does NOT cover accommodation and travel.

- **90 students online**. Registration fee: **250 euro** (VAT 22% included). The fee covers: remote access to all lectures; course material.

HOW TO APPLY: Prospective participants have to fill out and **submit the form** below, and **upload a 1-page letter** (pdf) organized as follows:

- name, department/university, current position (PhD student, postdoc, other)
- educational background
- research activity and interests
- motivations for participating in the school

Please note that **any page after the first one** will be automatically deleted.

PREREQUISITES: Basic notions and metrics on complex networks are required to be able to follow the entire course.

SELECTION CRITERIA: In addition to applicant quality, the Organizing Committee will consider a number of features including: the coherence of the motivation with the aim and scope of the school, the potential benefit for the student's research, the timeliness for the development of the student's career. Preference will be given to applicants not participating onsite in the previous edition (2022) of the school.

The school is especially addressed to **doctoral students** and **young postdoctoral scholars**. A very limited number of **senior students** (e.g., assistant/associate/full professors) can be admitted, if they provide strong and convincing motivation in their application letter.

Deadlines
- Student application: **February 26, 2023** *(firm deadline)*
- Notification of acceptance: **March 20, 2023**
- Registration and payment for accepted students: **April 3, 2023**

SHORT TALKS: Participants who intend to give a short talk (4 minutes) on **Thursday, May 25,** should declare it in the **application form** (see below) and provide a **title** and a list of **keywords** (from 3 to 5). As there will be room for no more than 25 talks, in case of a larger number of proposals the Organizing Committee will select on the basis of the potential interest to the audience, the coherence with the aim and scope of the school, and the diversification of topics.

Fee waivers

Subject to budget availability, the school will grant **5 fee waivers to onsite students** *(500 euros each) and* **5 fee waivers to online students** *(250 euros each) to support the attendance of PhD students and Junior Post Doctoral researchers.*

Prospective participants who are eligible for the grant should accompany their application (see the form below) with an email to the Organizing Committee (Carlo Piccardi, carlo.piccardi@polimi.it*) requiring the fee waiver, providing evidence of their current* **academic status** *and* **detailed motivations** *for their request.*

The acceptance will be notified together with the admission to the school (March 20, 2023).

SICC fee reduction

Members of the Italian Society for Chaos and Complexity (SICC) *are entitled for a discount of 50 euros on the admission fee. After the notification of acceptance, please contact Carlo Piccardi (*carlo.piccardi@polimi.it*) to inform about your membership.*

APPLICATION FORM

The application form for Complex networks: theory, methods, and applications (7th edition) is currently closed.

For information, please contact the Organizing Secretariat (Ms. Alessandra Cazzaniga – email: alessandra.cazzaniga@fondazionealessandrovolta.it) .

Venue and Accommodation

The School is housed in **Villa del Grumello,** Como, which is set in a park over Como lake.

How to get there

Click here for information on how to reach Como

Villa del Grumello is 20 min on foot from Como city center – you can also take a bus, lines 6 and 11 (bus stop: "Como Via Regina Piscine Villa Olmo", just after "Villa Olmo").

From the main Train Station (Como S. Giovanni), the nearest bus stop to catch line 6 and 11 is "Piazzale Rocchetto".

Click here for a map

Accommodation

Please notice that the cost of accommodation is NOT included in the admission fee.

Villa del Grumello has a **guest house** ("foresteria") with shared rooms (2- or 4-bed rooms). The rate is **45,00 euros** per night; breakfast is not included; a kitchen for self preparing breakfast is available). **Only shared accommodation with other students is allowed** (no accompanying persons).

A few rooms have been blocked in 3-star **hotels in Como**, with rates ranging from approx. 90 to 130 euros per night (breakfast included). The **School Secretariat** will take care of the accommodation of the accepted students who have accomplished the payment of the fee. Please contact the Secretariat to check availability and book (or get advice to book elsewhere).

Accommodation in shared rooms will be also available at Ostello Bello Como at a discount rate. Further details will follow.

IMPORTANT NOTICE for all school lecturers and attendees:

We have been informed that someone tried to contact school speakers and attendees offering travel arrangements (hotel and flight booking) on behalf of the school secretariat, asking for credit card details in order to proceed.

THIS IS A FRAUD*: these agencies are by no means authorized by the school.*

In case of doubt do not hesitate to contact the school secretariat (see page Contacts).