Universität Zürich[UZH]

UZH Blockchain Center

Syllabus

# Network Science

03SM22MI0019

## Autumn Semester 2023(HF23)

Prof. Dr Claudio J. Tessone

Blockchain & Distributed Ledger Technologies
Department of Informatics (IfI)
University of Zurich, Switzerland

# PREAMBLE

## *Welcome*

This course takes place every Autumn Semester. You will find all necessary information concerning the course within this Syllabus. From time to time, updates will be communicated on MS Teams and on the Blockchain & Distributed Ledger Technologies Group's webpage at IfI (http://www.ifi.uzh.ch/bdlt).

We are very happy to welcome you to our lecture.

**Prof. Dr Claudio J. Tessone**
Blockchain & Distributed Ledger Technologies Group
Department of Informatics
Faculty of Business, Economics, and Informatics
University of Zurich

# • QUICK OVERVIEW

## *Module coordinator*


- Prof. Dr Claudio J. Tessone

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  **Meetings are online (MS Teams, or equivalent) after previous appointment.**

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## *Instructors*


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## *Details*

**Type:** Lecture
**Target Audience:** This course is acknowledged for MA students and is assigned to the Core elective areas „Wahlpflichtbereich":

- Information Systems (INF1), Data Science (INF5), Artificial Intelligence (INF6)
- Marketing (BMC)
- OEC elective area

**Frequency:** Each Fall Semester
**AP (ECTS):** 6
**Language:** English

## Prerequisites

Fundamental courses in statistics (e.g. Empirical Methods, Programming). Solid programming skills (or the willingness to develop this knowledge **prior** to the lecture) are a necessary requirement. The programming language in which the exercises are to be solved is not relevant. We can support you if the code is written in Python, R, etc. **Python will be used during the exercises as example.**

## Content:

A detailed introduction to the most paradigmatic network science methods and network generation models with a focus on understanding the aims and applications of this branch of science.

## Learning outcome:

At the end of the course students: - are able to construct network representations of complex datasets - characterise and understand topological properties of networks - know the typical characteristics of networks in social, economic and technology systems - can understand mechanisms that lead to the emergence of large scale network properties

## Grading:

Assignments given in class + Final Exam.

## Further information:

https://www.ifi.uzh.ch/en/bdlt/Teaching/Blockchain-and-Crypto-Economics.html

## Registration:

Through the registration tools at the University of Zurich.

# 1. Introduction and Objectives

Network Science is an interdisciplinary field of research that has become synonym with the study of multiple complex systems that pervade social and economic systems. Network refer to representations of systems whose constituents are linked together because of social ties, information flow, economic relations, etc. Network modelling is a methodology with ample applications in modern data-intensive fields which has multiple applications in management, marketing, informatics, among multiple others.

The course covers a wide range of topics: it starts with an introduction to the basic concepts about networks; it then deals with the most important properties that real-world networks exhibit, and how they can be modelled; then, it introduces network analytic techniques to uncover the most important properties of empirical networks. Finally, an introduction to the diffusion of technologies, opinions and rumours (and viruses!) are taught. During the course, special emphasis is employed in introducing network analysis and visualisation tools.

The course is highly interactive. All the lectures consist of a theoretical part, then, the students must develop (in small groups and always supported by the instructors) the some practical exercises themselves. This permits them to gain direct experience and familiarity with the concepts taught and the techniques involved. In this participatory environment, multiple exercises and the creation of visualisations play an important role.

# 2. Course Contents

LECTURE 1. Kickoff and Introduction to Network Theory (CT) [18.09.23]

. What is a network?
. Degree
. Degree Distribution
. Network visualisations
. Introduction to software packages: networkx

LECTURE 2. Higher order network properties (CT) [25.09.23]

. Degree distributions
. Paths, walks and distances
. Network structure and communities
. Networks and complexity
. The approach to network analysis
. Network Randomisation approaches

LECTURE 3. Centrality measures and ranking nodes (CT) [02.10.23]

. Degree centrality
. Closeness centrality
. Betweenness centrality
. Eigenvector centrality
. Google's PageRank
. Edge-based centralities

LECTURE 4. Random graph models and Small World (NV) [09.10.23]

. Emergence of random networks
. Erdos-Rényi model
. Binomial vs. Poisson
. Giant components
. Real networks are not Poisson
. 6 degrees of separations in social networks
. Watts and Strogatz model
. Diameter and clustering

LECTURE 5. Community Detection (CT) [16.10.23]

. Modularity
. Modularity Maximisation
. Practical introduction to Community Detection Algorithms
. Label propagation
. Leading eigenvector
. Multilevel
. Edge betweenness

LECTURE 6. Scale-free networks (CT) [23.10.23]

. Scale invariance and power laws; the difference with other statistics
. Preferential attachment: the growth of social networks
. Copying model
. Preferential attachment with fitness: the relationship with adoption

LECTURE 7. Statistical Inference of network models (NV) [30.10.23]

. The maximum entropy principle
. Exponential Random Graph Models
. Solvable vs non-solvable models: MCMCMLE
. Statistically Validated Networks

LECTURE 8. Financial networks and time-series networks (NV) [06.11.23]

. Debt exposure Networks and systemic risk
. Correlation Minimal Spanning Trees
. Transaction Networks
    . Lead-lag networks

LECTURE 9. Percolation and robustness (NV) [13.11.23]

. Percolation and phase transitions
. Resilience and robustness of networks
. Targeted attacks and ranking strategies
. Cascading failures
. Branching models

LECTURE 10. Spreading phenomena I (CT) [20.11.23]

. Compartmental models of epidemic spreading
. The relationship with rumour and information spreading
. Epidemic threshold in unstructured populations
. Immunisation strategies
. Influence identification

LECTURE 11. Spreading phenomena II and temporal networks (NV) [27.11.23]

. Epidemic forecast and prediction
. Effect of network topology on spreading
. Absence of epidemic threshold in complex networks
. Temporal networks

LECTURE 12. Social Networks, Social Contagion and Collective Behaviour (JH) [04.12.23]

. Social influence network theory
. Influential spreaders
. Influential nodes vs. influential links
. Centrality measures for influencers identification

LECTURE 13. Models of Consensus and Social Influence (NV) [11.12.23]

. Imitation, herding
. Coordination and anti-coordination
. Voter model
. Ising model
. Majority models

LECTURE 14. Wrap-up [18.12.23]

. Discussion of exercises and further topics

# 3. Course Material

## *Material Offered*

Students have access to an Olat course where all the slides presented in class, relevant material, datasets and literature can be found.

## *Overview of classes*

On the webpage an overview of all classes given by our team can be found. Develop an idea of the classes and how they best fit into your personal agenda. Keep in mind that network science classes are only offered once a year.

## *Syllabus*

For each course, a detailed syllabus exists with all details concerning that specific course. This is your guideline for the class and a MUST read. You'll find everything in here concerning the grading of the course, the agenda, the planned topics and much more...
The main materials used in this course are Bibliography and the Slides.

## *The Slides*

The slides presented and discussed in class are available in a digital format. You can download the slides to each class. The slides do not completely cover the entire Syllabus; therefore, it is necessary to participate in the class. All slides will be distributed after each module. All our slides follow our detailed standardised slide format. All presentations in the classroom also must follow this format.

All course slides, recordings of the lectures, the assignments (and sample solutions after their due date) will be given on a dedicated Team on MS Teams communicated to all students.

# 4. Reading

## *Bibliography*

- F. Menczer, S. Fortunato, C.A. Davis. A First Course in Network Science (2020, Cambridge University Press)
- A. L. Barabási. Network Science (2016, Cambridge University Press)

Recommended readings:

- M. E. J. Newman. Networks: An introduction (2010, Oxford University Press)
- G. Caldarelli, Scale-Free Networks: Complex web in nature and technology (2007, Oxford University Press)
- G. Caldarelli and A. Chiessa. Data Science and Complex Networks (2018, Oxford University Press)
- A. Barrat, M. Barthélémy and A. Vespignani, Dynamical Processes on Complex Networks (2008, Cambridge University Press)

## *Related scientific journals*

- *Proceedings of the National Academy of Science*
- *Scientific Reports*
- *PLOS ONE*
- *Journal of the Royal Society: Interface*
- *Physical Review E*
- *Physical Review Letters*
- *Journal of Artificial Societies and Social Simulation*
- *American Economic Review*
- *American Journal of Sociology*

# 5. Application Procedure

Please enrol to the course using the usual UZH planning tools. In case of doubts, contact the instructor of the booking service of the Faculty.

*E-mail:* modulbuchung@oec.uzh.ch

# 6. Evaluation

There are two parts in the evaluation of this module: assignments and final examination. The final evaluation will be determined at 50% from the grades received in the assignments, and 50% form the final examination grade. Students need to pass both the assignments and the final examination in order to pass the course.

## *6.1 Assignments*

The conduct of this course is based on student inquiry and practice related to the assignments. To gain practical experience in Network Science and the related methods are a fundamental part of the course.

During the module, you will have to perform different assignments (graded). You will have to hand them in for correction within the deadlines to be provided on the first lecture. Sample solutions will be provided to you during the course.

The assignments will be presented after the theoretical lecture and followed by Q&A sessions. While non-mandatory, we strongly recommend that you to participate in these practical sessions.

## *6.2 Final exam*

There is a final written exam on the subjects taught during the course. We believe this is a subject whose depth can be best learnt by doing: Therefore, there are extensive practice sessions where the students get in-depth exercises on the main topics in the area.

# 7. Academic Fraud

The Code of Honour of the University of Zurich applies to all work in this course and will be strictly enforced. The intent of the Honour Code in this course is to ensure that each student claims and receives credits for his/her own efforts. Violations to this are considered academic fraud.

### Definition

Academic fraud is an act by a student, which may result in a false academic evaluation of that student or of another student. Plagiarism is understood as the use or imitation of another people's work, either wholly or partially, without acknowledging the source and the author. In principle, plagiarism is an infringement of copyright law. Short passages from another author may be quoted.

All documents you will hand-in are going to be checked by software and manually for plagiarism. Documents with a score above 10% are going to be intensively validated and in suspicious cases we hand-out penalties for fraud behaviour.

# 8. Administrative Comments

## *8.1 Course format*

**Lectures.** As of 01.09.2023, all lectures will be held onsite. Attendance is non mandatory but highly recommended. Lectures are - in general - one hour long.

**Q&A Sessions.** Once a week, Q&A sessions will take place on MS Teams on a Meeting in the General Channel. These are non-mandatory (you only need to join the meeting). *They will not be recorded.*

## *8.2 Getting in contact with us*

- The first option for you is to contact us on the General Channel on MS Teams (and eventually other channels when appropriate) if the question is relevant to all students. This channel is there for you to post questions, and we will strive to have a rapid answering time. If it is a bilateral question, we suggest you write on MS Teams on a bilateral chat.
- We will strive to provide you with speedy answers to the questions posted on MS Teams.
- You can reach us either bilaterally (if it is a matter that concerns only you), or through the appropriate, common channels (in case your question may be of help to others).

*We do not guarantee answering e-mail communication*

## *8.3 Students with disabilities*

Any student with a documented disability needing academic adjustment or accommodation is requested to speak with the instructors during the first two weeks of class. All discussion will remain confidential. Students with disabilities will need to also contact the directors of the Faculty.

## *8.4 Laptops*

Laptops or equivalent computing devices are needed in for the sole purpose of supporting the individual learning process.