ACE Network Subject Information Guide

Random Graphs vs. Complex Networks
Semester 1, 2019

Administration and contact details

Host Department	School of Mathematics and Statistics
Host Institution	The University of Sydney
Name of lecturer	A/Prof. Eduardo G. Altmann
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Subject details

Handbook entry URL	
Subject homepage URL	http://www.maths.usyd.edu.au/u/ega/teaching/networks2019/
Honours student hand-out URL	
Start date:	28/2
End date:	31/5
Contact hours per week:	2
Lecture day and time:	Monday 11AM and Thursday 11AM (Tentative)
Description of electronic access arrangements for students (for example, WebCT)	

Subject content

1. **Subject content description**

The representation of the relationship (links) between objects (nodes) in form of a network is increasingly popular in social, economical, biological, and technological sciences. Real-world examples of networks coming from these various fields show striking differences to the random-graph models proposed by mathematicians (in the mid XX century). For instance, real networks show (i) a large number of triangles, short loops, and other small subgraphs which are absent in simple random-graph models; and (ii) the distribution of the number of links that nodes receive deviates from a Binomial and shows large skewness (fat-tailed distribution). The goals of this course are to characterize these disagreements between complex networks and random graphs, to show why they matter, and to present more advanced mathematical methods to model complex networks. The course will start with a general introduction to the field of complex networks, discussing different examples of networks and how to characterize them (e.g., clustering and centrality measures). We will then introduce and apply computational methods to empirically-measured networks. The main part of the course will be the definition and characterization of different random-graph ensembles. Some significant deviations between random graphs and real networks will be explored, with focus on the small-world effect, the fat-tailed degree distribution, and the consequences to network robustness. In the final part of the course we will discuss how more advanced random-graph ensembles (e.g., exponential random-graph models) can be used to characterize real-world networks. This will be interpreted in terms of – and serve as an introduction to – more general ideas and methods, such as the Principle of Maximum Entropy and Importance Sampling Monte Carlo methods (e.g., the Metropolis Algorithm). This course involves computer simulations and data analysis. Familiarity with a programming language (e.g., Python or Matlab) and basic statistical concepts are desired.

2. Week-by-week topic overview

Week | Date	Topic		Computation Tasks
1 (28/2)	I - Introduction	Motivation, definitions, notation	Visualize Networks
2	II -Network Characterization:	Local and global measures	Compute measures
3		Centrality Measures	Compute most central nodes
4	III - Network Models	Poisson Random Graphs	Generate networks
5		Small World Networks	Simulate WS model
6		Scale-free networks	
7		Random graphs, Maximum Entropy Principle, ERGMs	Shuffling links
8		Importance Sampling, Stochastic Block Models	Choice of Projects
Break (22/4)		1 Week break	
9 (29/4)	IV – Network Resilience	Percolation and random failures	Project
10		Targeted attacks	Project
11	V – Dynamics on Networks	Cascades, Epidemics, etc.	Project
12		Project Presentation	
13 (27/5)	Project Presentation(?)		
14 or 15	Exam	Exam	

3. **Assumed prerequisite knowledge and capabilities**

   Linear Algebra; Computational Language;

4. **Learning outcomes and objectives**

   Develop analytical, numerical, and modeling skills that help to connect abstract mathematical ideas to real-world systems represented as networks.

AQF specific Program Learning Outcomes and Learning Outcome Descriptors (if available):

AQF Program Learning Outcomes addressed in this subject	Associated AQF Learning Outcome Descriptors for this subject
Insert Program Learning Outcome here	Choose from list below
Insert Program Learning Outcome here	Choose from list below
Insert Program Learning Outcome here	Choose from list below
Insert Program Learning Outcome here	Choose from list below
Insert Program Learning Outcome here	Choose from list below
Insert Program Learning Outcome here	Choose from list below
Insert Program Learning Outcome here	Choose from list below

Learning Outcome Descriptors at AQF Level 8

Knowledge

K1: coherent and advanced knowledge of the underlying principles and concepts in one or more disciplines

K2: knowledge of research principles and methods

Skills

S1: cognitive skills to review, analyse, consolidate and synthesise knowledge to identify and provide solutions to complex problem with intellectual independence

S2: cognitive and technical skills to demonstrate a broad understanding of a body of knowledge and theoretical concepts with advanced understanding in some areas

S3: cognitive skills to exercise critical thinking and judgement in developing new understanding

S4: technical skills to design and use in a research project

S5: communication skills to present clear and coherent exposition of knowledge and ideas to a variety of audiences

Application of Knowledge and Skills

A1: with initiative and judgement in professional practice and/or scholarship

A2: to adapt knowledge and skills in diverse contexts

A3: with responsibility and accountability for own learning and practice and in collaboration with others within broad parameters

A4: to plan and execute project work and/or a piece of research and scholarship with some independence

5. Learning resources

References:

- Networks: An Introduction, Mark Newman, Oxford Univ Press, 2010.
- Network Science book, L. Barabasi, 2017 http://barabasi.com/networksciencebook/
- Dynamical Processes on Complex Networks , A. Barrat, M. Barthélemy, A. Vespignani, Cambridge University Press, 2012
- Statistical mechanics of complex networks, R. Albert & A. Barabasi, Rev. Mod. Phys. 2002.
- The Structure and Function of Complex Networks, M. Newman, SIAM Review, 2002.

Software for computation:

- Networkx: https://networkx.github.io
- graphtool: https://graph-tool.skewed.de
- igraph: http://igraph.org
- Pajek: http://vlado.fmf.uni-lj.si/pub/networks/pajek/
- Jupyter Notebooks: http://jupyter.org

Network data:

- KONECT: http://konect.uni-koblenz.de
- SNAP http://snap.stanford.edu/data/index.html
- SOPSAHL http://toreopsahl.com/datasets
- Index of Complex Networks - University of Colorado Boulder: https://icon.colorado.edu/

6. Assessment

Exam/assignment/classwork breakdown					
Exam	40%	**Assignment**	30 %	**Class work**	30%
Assignment due dates		(approx. 14/3)	(approx. 28/3)	(approx 14/4)	(approx. 28/4)
Approximate exam date				7/6	

Institution Honours program details

Weight of subject in total honours assessment at host department	Click here to enter text.
Thesis/subject split at host department	Click here to enter text.
Honours grade ranges at host department:	
H1	Enter range %
H2a	Enter range %

H2b	Enter range %
H3	Enter range %