Network Science: Theory, Methods, and Applications
GRAD 700R
Spring Semester, 2013

Course Description: Over the last two decades there has been an explosion in the use of networks to describe a variety of phenomena, modeling areas as disparate as Greek archaeology to NCAA football and almost everything in between. In addition, network scientists are rapidly compiling new insights about networks themselves, for instance, showing commonalities of patterns of networks working at levels from global (transportation networks) to that of organizations (corporate networks) to that of people (social networks) to the cellular and molecular levels (protein networks).

Network science is a vast and rich topic, and thus we cannot hope to plumb its full depth in one semester. We aim to deal with topics of immediate interest to a team of Emory faculty who are using the tools of this discipline in their current research programs. Students will have the opportunity to explore areas of particular interest to them in their research projects.

Course Objectives: Upon completion of this class, the successful student will be able to 1) define key concepts of network science; 2) apply network science theory and methods to interpret problems in their area of interest in network terms; and 3) manipulate and analyze network data pertaining to a problem of interest.

Class Meetings
Officially, Mondays and Wednesdays, 4 – 5:15 pm.
Unofficially, Mondays and Wednesdays, 4:15 – 5:30 pm.

Class Organizer
Vicki Stover Hertzberg, Ph.D.
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TA
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Office Hours
Dr. Hertzberg: TR 8 – 9 am; other hours by appointment
Ms. Mehta: MW 2-4 pm; other hours by appointment

Course requirements: Students are responsible for readings and discussion each week. Part of this work will include writing short responses to questions (weekly homework), writing up the lab assignments, giving brief reports, posting and commenting on the class blog, and being responsible for leading discussion on a particular subject or reading. In addition, each student will pursue a research project on which he or she will write a term paper and make a poster presentation.

Evaluation: Students will be evaluated on the basis of several components, described below. Students will be expected to attend class and to participate. Homework and lab assignments will be given weekly and students must turn these in one week after assignment. There will be a class blog on which students will be expected to post twice during the semester. There will be a final project as well, with a poster presentation and term paper associated with it**.**

Grades will be given according to a combination of these components, weighted according to the following table:

Component	Weight	Basis of Evaluation
Class Participation	6%	Thoughtfulness, originality, activity
Homework assignments	24%	Correctness, quality of write-up
Lab assignments	25%	Correctness, quality of write-up
Blog entries	20% (2% for each post, 1% for each comment, 2% for inviting successful guest post)	Thoughtfulness, correctness, clarity
Final Project	25% (5% for Milepost 1, 5% for Milepost 2, 15% for Poster presentation)	Results, conclusions, thoughtfulness, content, depth, visual aids, clarity

Textbook(s)

There is no assigned textbook. Reading assignments will be made each week. However, many people feel better about having a textbook. Here are a few suggestions, two of which are free, and others that are not.

Free

Introduction to Social Network Methods. Robert Hanneman and Mark Riddle.
http://faculty.ucr.edu/~hanneman/nettext/

Network Science. Albert-László Barabási (only 4 chapters available)
http://barabasilab.neu.edu/networksciencebook/

Alternatives (for purchase):

Networks: A Very Short Introduction. Guido Caldarelli & Michele Catanzano
See http://www.amazon.com/Networks-Very-Short-Introduction-Introductions/dp/0199588074/ref=sr_1_1?ie=UTF8&qid=1354637712&sr=8-1&keywords=caldarelli

Networks, Crowds, and Markets. David Easley & Jon Kleinberg
See http://www.amazon.com/Networks-Crowds-Markets-Reasoning-Connected/dp/0521195330/ref=sr_1_1?ie=UTF8&qid=1357574802&sr=8-1&keywords=david+easley

Social Network Analysis: Methods and Applications. Stanley Wasserman & Katherine Faust
See http://www.amazon.com/Social-Network-Analysis-Applications-Structural/dp/0521387078/ref=sr_1_1?s=books&ie=UTF8&qid=1354637776&sr=1-1&keywords=stanley+wasserman

Social and Network Methods. Matthew Jackson
See http://www.amazon.com/Social-Economic-Networks-Matthew-Jackson/dp/0691148201/ref=sr_1_1?s=books&ie=UTF8&qid=1354637849&sr=1-1&keywords=jackson+networks

The Structure of Complex Networks. Ernesto Estrada
See http://www.amazon.com/Structure-Complex-Networks-Theory-Applications/dp/019959175X/ref=sr_1_1?s=books&ie=UTF8&qid=1354637906&sr=1-1&keywords=ernesto+estrada

Social Networks and Health: Models, Methods, and Applications. Thomas Valente.
See http://www.amazon.com/Social-Networks-Health-Methods-Applications/dp/0195301013/ref=sr_1_1?s=books&ie=UTF8&qid=1354637951&sr=1-1&keywords=thomas+valente

Six Degrees: The Science of a Connected Age. Duncan Watts
See http://www.amazon.com/Six-Degrees-Science-Connected-Market/dp/0393325423/ref=sr_1_3?s=books&ie=UTF8&qid=1354638025&sr=1-3&keywords=Duncan+watts

Linked: How Everything Is Connected to Everything Else, and What It Means. Albert-László Barabási
See http://www.amazon.com/Linked-Everything-Connected-Else-Means/dp/0452284392/ref=sr_1_1?s=books&ie=UTF8&qid=1354638140&sr=1-1&keywords=barabasi

Bursts: The Hidden Patterns Behind Everything We Do, from Your E-mail to Bloody Crusades. Albert-László Barabási
See http://www.amazon.com/Bursts-Hidden-Patterns-Everything-Crusades/dp/B0064XDKTA/ref=sr_1_3?s=books&ie=UTF8&qid=1354638159&sr=1-3&keywords=barabasi

Dates for Assignments

Written assignments must be double-spaced, single-sided, documents with font size of 12 or greater. Late assignments will not be accepted without prior arrangement. The files must be in PDF format. The naming convention is as follows:

For Homework assignments*: yourlastname_homeworkn*.pdf
For Mileposts: *yourlastname_milepostn*.pdf
For Lab assignments: *yourlastname_labn*.pdf

Date	**What is Due Then?**
January 22	Blog posts* (A-L); Blog Comments* (M-Z)
January 23	Homework 1*
January 27	Blog posts (M-Z); Blog Comments (A-L)
January 30	Milepost 1*
February 3	Blog posts (A-L); Blog Comments (M-Z)
February 4	Lab 1*
February 10	Blog posts (M-Z); Blog Comments (A-L)
February 11	Lab 2
February 17	Blog posts (A-L); Blog Comments (M-Z)
February 18	Lab 3
February 24	Blog posts (M-Z); Blog Comments (A-L)
February 25	Lab 4
March 3	Blog posts (A-L); Blog Comments (M-Z)
March 4	Lab 5
March 17	Blog posts (M-Z); Blog Comments (A-L)
March 20	Milepost 2
March 24	Blog posts (A-L); Blog Comments (M-Z)
March 27	Homework 2
March 31	Blog posts (M-Z); Blog Comments (A-L)
April 3	Homework 3
April 7	Blog posts (A-L); Blog Comments (M-Z)
April 10	Homework 4
April 14	Blog posts (M-Z); Blog Comments (A-L)
April 17	Homework 5
April 24	Homework 6
April 29	Poster

*Blog posts are due at 6 pm on the assigned date. Blog comments are due at 11 pm on the assigned date. Homework, lab assignments, and mileposts must be uploaded to Blackboard by 6 pm on the date indicated.

A Word about the Blog: The purpose of the blog assignment is to stimulate a robust virtual discussion. Thus you are free to post and to comment more frequently than assigned. The blog assignments are due on Sunday evening so that everyone can read them prior to the class meetings on Monday and Wednesday.

Class Blog Posts: Each week half of the students will be expected to post their reflections on the coming week's readings, and half the students will be expected to comment on one or more of the current week's posts. The next week the groups will alternate. Each blog post should be at least 250 words for undergraduate students, 400 words for graduate students. Posts should address the strengths and weaknesses of the readings and what further areas of investigation arise.

Class Blog Comments: There is no word limit criterion for blog posts, but they are expected to be substantive. Thus rather than posting "I agree completely," state why you agree. Posts are expected to be respectful. This does not mean that you cannot disagree with someone. Instead you should state your counterargument, rather than simply calling someone a knucklehead.

A Final Word about the Blog: At least once in the semester you are expected to email one of the authors of the readings to invite her/him to comment on a blog post.

Sessions, Topics, and Reading Assignments

Date	*Presenter(s)*	*Topic*
1/14	**Vicki Hertzberg**	**Course Intro; Network Science – A Brief History**
	Ron Gould	**Basic Concepts**

Description
Professor Hertzberg will give a brief history of network science, highlighting the parallel developments in the fields of mathematics, physics, and sociology. Professor Gould will give an overview of the basic concepts of networks, establishing common vocabulary.

Reading
Networks, A Very Short Introduction. Guido Caldarelli and Michele Catanzaro. Chapters 2-4, 6.

Networks, Crowds, and Markets. David Easley and Jon Kleinberg. Chapter 2 (all), Chapter 3 (sections 1 and 2).

1/16 **Michele Benzi** **The Network Spectrum**

Description
In this lecture we will cover the notions of subgraph centrality and communicability, both of which have found widespread use in the analysis of complex networks. The main underlying idea is to exploit the fact that in real-world networks, there are many routes between two nodes besides the shortest path. Taking this into account results in more robust and effective means to rank the centrality of nodes and to measure the flow of information between nodes. From the mathematical point of view, these metrics can be expressed in terms of functions of the adjacency matrix (or of the graph Laplacian) associated with the network. In turn, these can be described using spectral graph theory, i.e., in terms of the eigenvalues and eigenvectors of the various graph matrices. These concepts have been successfully applied to the study of protein-protein interaction networks and in the analysis of social conflicts. Other potential applications include the spreading of rumors, or fads, in social networks as well as the spreading of viruses over computer networks.

Reading
E. Estrada, *The Structure of Complex Networks*. Oxford U. press, 2011.

E. Estrada, N. Hatano and M. Benzi, "The physics of communicability in complex networks", *Physics Reports*, 514 (2012), pp. 89-119.

1/21 **MLK Day – NO CLASS**

1/23 **M. Grigni** **Network Structure and Formation**

Description
Professor will continue the discussion of fundamental network structures, such as betweenness and homophily. He will give particular attention to the algorithmic problem of partitioning such networks.

Reading
Networks, Crowds, and Markets. David Easley and Jon Kleinberg. Chapter 3, section 6, and Chapter 4, sections 1-4.

1/28 **Lab 1** **Intro to Gephi**

1/30 **Stefan Boettcher** **TBN**

2/4 **Lab 2** **Gephi 2**

2/6 **Sandra Blakely** **Networks in the Greek and Roman World World**

Description
Network analysis is both promising and problematic for archaeological research in the Greek and Roman world. The promise is the correlation to the intellectual models and the lived experience of our objects of study. Plato referred to the cultures of the ancient Mediterranean as frogs around a pond; behind his metaphor was a historical reality of geographically scattered groups who relied on long-distance networks for economic, political and military success. The challenge is the data at our disposal, which are preserved only partially and often in extremely fragmentary condition, as well as the variations in the critical application of network analysis. We will review several of these applications, and then consider how network analysis may be brought to the Mystery cult of the Great Gods of Samothrace.

Readings
Brughmans, T. Connecting the Dots: Towards Archaeological Network Analysis, *Oxford Journal of Archaeology* 29(3) (2010) 277-303;

Burkert, W. Concordia Discors: the literary and the archaeological evidence on the sanctuary of Samothrace, 179-191 in N. Marinatos, R. Hagg, ed.s *Greek Sanctuaries: New Approaches* (Routledge 1993).

2/11 **Lab 3** **Gephi 3**

2/13 **TBA**

2/18 **Lab 4** **Gephi 4**

2/20 **Mike Prietula** **TBN**

2/25 **Lab 5** **Gephi 5**

2/27 **Monica Capra** **Complex Networks in Economics**

Description
Not surprisingly, recent theoretical and methodological advances in Complex Networks have impacted how we model and analyze economic interactions. There are applications of Complex Networks to a variety of areas in economics including Industrial Organization, Information Economics, International Trade, Finance, and Labor Economics. Yet, the area that may be most impacted by these new theories and methods is Development Economics. In this session, Professor Capra will present an overview of the main applications of Complex Networks in economics, emphasizing how CN has impacted how we see economic development.

Readings
C. Hidalgo, B. Klinger, A.L. Barabasi, R. Hausmann. The product space conditions the development of nations. *Science*, 317 (2007), pp. 482–487

César A. Hidalgo and Ricardo Hausmann. The building blocks of economic complexity. *PNAS* June 30, 2009 vol. 106 no. 26 10570-10575

Reyes, Javier, Stefano Schiavo, and Giorgio Fagiolo. 2010. Using Complex Networks Analysis to Assess the Evolution of International Economic Integration: The Cases of East Asia and Latin America. *Journal Of International Trade And Economic Development* 19, no. 2: pp. 215-239

3/4 **David Davis** **TBN**

3/6 **Roberto Franzosi** **TBN**

3/11 **Spring Break – NO CLASS**

3/13 **Spring Break _ NO CLASS**

3/18 **A. Veneziani** **TBN**

3/20 **Brad Pearce** **Application of network analysis software and web-based databanks in molecular pathophysiology research.**

Description
Human disease typically involves disruption of molecular networks as opposed to isolated abnormalities in an individual gene or protein. Advances in "-omics" technologies holds the promise to measure molecular differences between individual people, and discern underlying pathways of disease causation. However, this requires bioinformatic approaches to elucidate complex multilevel interactions between molecules, cells, and tissues. We will overview web-based software designed to facilitate this understanding, and work-through examples with one of these tools using data from a case-control study.

Reading
Gene Set Analysis and Network Analysis for Genome-Wide Association Studies. Inti Pedroso and Gerome Breen. *Cold Spring Harb Protoc* 2011; doi: 10.1101/pdb.top065581

3/25 **Ned Waller** **TBN**

3/27 **Doug Lowery** **Interpersonal Social Contacts in the ED**

4/1 **Gonzalo Vazquez** **TBN**

4/3 **Lance Waller** **Adding geographic location to network analysis: Examples from veterinary outbreaks.**

Description
Social networks provide a powerful way to assess contacts between infectious and susceptible individuals and influence the subsequent spread of infection. However, social interactions also occur in geographic space. In this session, we will explore how spatial locations can influence network analyses. The three papers explore this with respect to infectious disease in animals and illustrate how to incorporate geographic and social distance in attempts to control the spread of an outbreak.

Reading
Firestone SM, Ward MP, Christley RM, and Dhand NK (2011) The importance of location in contact networks: Describing early epidemic spread using spatial social network analysis. *Preventive Veterinary Medicine* **102**, 185-195. Doi: 10.1016/j.prevetmed.2011.07.006

Firestone SM, Christley RM, Ward MP, and Dhand NK (2012) Adding the spatial dimension to the social network analysis of an epidemic: Investigation of the 2007 outbreak of equine influenza in Australia. *Preventive Veterinary Medicine* **106**, 123-135. Doi: 10.1016/j.prevetmed.2012.01.020

Bajardi P, Barrat A, Savini L, and Colizza V (2012) Optimizing surveillance for livestock disease spreading through animal movements. *Journal of the Royal Society Interface* **9**, 2814-2825. doi: 10.1098/rsif.2012.0289

4/8	**Hannah Cooper**	**TBN**
4/10	**Ralph DiClemente**	**TBN**
4/15	**Julia Painter**	**TBN**
4/17	**Claire Sterk**	**TBN**
4/22	**Solveig Argeseanu**	**Friendships, health, and health behaviors**
4/24	**Vicki Hertzberg**	**More on Interpersonal Contacts**
4/29	**Student Groups TBN**	

Academic Integrity

Please remember that the Emory University Honor Code applies to all work in this class.