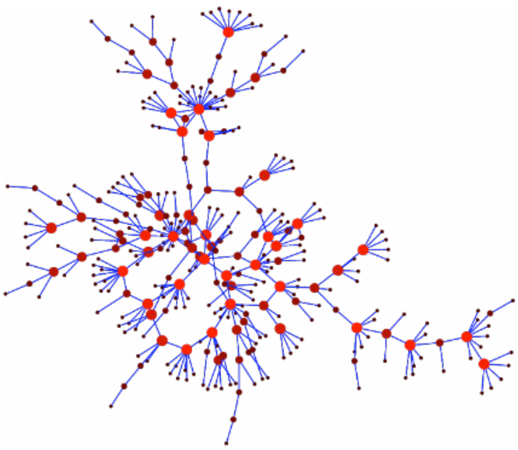
REGLERTEKNIK LTH KURSINFORMATION

NETWORK DYNAMICS

FRTN30 (VT LP2, 7.5 hp)



Why studying network dynamics?

Networks permeate our modern societies. Everyday, we exchange information through the World Wide Web and other comminucation networks, modify our opinions and take decisions under the influence of our social interactions, commute across road networks, buy goods made available to us by production and distribution networks, use electrical power, gas and water that infrastructre networks bring directly to our homes, invest our savings in highly interconnected networks of financial funds, ...

This course will focus on common principles at the heart of the functioning of these networks and on how the same notions related to resilience, fragility, centrality, and connectivity arise in several different domains. It will both introduce mathematical tools from graph theory, random graphs, probability, dynamical systems, optimization and game theory, and cover a wide variety of applications including: opinion dynamics and learning in social networks; economic and financial networks; communication networks and the Internet; averaging and consensus; spread and control of epidemics; dynamics and control of transportation and power networks.

The course

The course is offered annually during VT LP2 starting from Spring 2015 and is worth 7.5 hp. There will be 14 lectures, 14 exercise sessions, and 4 home assignments. Lectures will be offered in English.

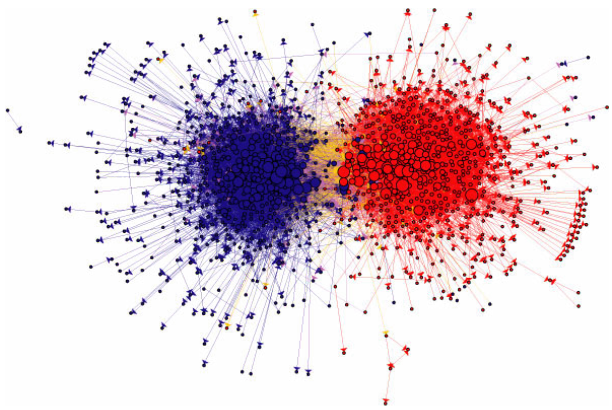
Aim

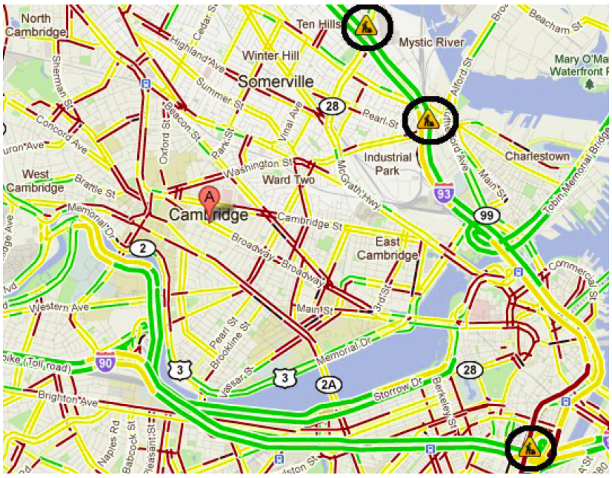
The aim of the course is to introduce the student to basic yet rigorous methods for the analysis and design of different emerging phenomena in networks. The emphasis will be on tools that allow to relate such behaviors to the network structure and the dynamical behavior of its single composing units.

Contents

During the course you will become familiar with the following topics:

- Graph Theory: adjecency matrix, paths, connectivity, special graphs such as trees, cycles;
- Markov Chains: invariant distribution, mixing, hitting times and probabilities, coupling;
- Linear Dynamical Systems on networks: positive systems, averaging and consensus, compartmental models;
- Network Flows: max-flow min-cut theorem, optimal transport, dynamical flows, efficiency and resilience measures, Wardrop equilibria, price of anarchy;
- Game Theory: Nash equilibrium, positive and negative externalities, potential games, (noisy) best responses, evolutionary dynamics;
- Random Graphs: Erdos-Renyi, configuration model, preferential attachment, small world;
- Epidemics and other interacting systems on networks: SI, SIR, SIS, linear threshold models, cascading failures, percolation, branching process.





Applications

While emphasizing rigorous methodology and common principles, this course will explain how the different tools are relevant in specific real-life applications. E.g., it will be shown: how to rate the importance of web pages; how to predict the influence of a group of individuals in a social network; how to efficiently aggregate information collected by many sensors in order to estimate an unknown quantity; how to predict when opinion dynamics on a social network will converge to a consensus or when disagreement will persist; how to design effcient and resilient power or traffic flows; how to design mechanisms that stir individuals' self-interested behaviors towards a socially desirable aggregate behavior; how to predict and control the spread of epidiemics in a network; how to facilitate the diffusion of a new product in a networked market.

Course material

The course will preliminary be based on lecture notes prepared by the lecturer. There is no single textbook covering the whole material. One which goes close to that is

- M.E. J. Newman, *Networks: an Introduction*, Oxford University Press, 2010.

Supplementary readings, with more focus on some specific parts of the course, include:

- M.O. Jackson, *Social and Economic Networks*, Princeton University Press, 2010.
- D. Easley and J. Kleinberg, *Networks, Crowds, and Markets: Reasoning About a Highly Connected World*, Cambridge Univ. Press, 2010.
- M. Chiang, *Networked Life: 20 Questions and Answers*, Cambridge University Press, 2012.
- D.A. Levin, Y. Peres, and E.L. Wilmer, *Markov Chains and Mixing Times*, American Mathematical Society, 2009.

Examination

The course will be examined by four hand-ins and a final written exam.

Master theses

Being focused on topics close to the state of the art in the fast-growing research area in networks, this course will be a natural basis for master thesis projects. Specific project proposals will be made availble to the interested students.

More information

For up-to-date information about this course please visit the course webpage

`http://www.control.lth.se/FRTN30`

You are also welcome to contact the lecturer Giacomo Como (giacomo.como@control.lth.se).

More information about the department of Automatic Control and our courses can be found at

`http://www.control.lth.se/education/`

The first image in the previous page represents the network of sexual contacts redrawn from J.J. Potterat *et al.*, 'Risk network structure in the early epidemic phase of HIV transmission in Colorado Springs', Sex Transm. Infect., pp. 159–163, 2002. The second image in the previous page represents the hyperlink connections among political blogs before the 2004 US presidential election, as drawn in L. Adamic and N. Glance, 'The Political Blogosphere and the 2004 U.S. Election: Divided They Blog', *Proc. 3rd Int. workshop on Link discovery*, pp. 36–43, 2005. The two images in this page are, respectively, the road network in Cambridge, Massachussets, as seen in Google Maps on 11/7/2011 at 18:30 *ca.*, and the Swedish national power transmission grid.