ECE 780 T09 Project

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Project description

Each student will investigate a topic of their choosing in the area of network/graph theory, multi-agent systems, distributed systems/control/optimization, or any related area. You will

(i) learn with breadth, by researching a topic outside the immediate scope of the lecture material,

(ii) learn with depth, by formally writing a report about your chosen topic, and

(iii) develop your technical presentation skills, by conveying a bit of what you have learned to your colleagues in an oral presentation.

As the project is intended to accommodate a wide variety of student interests and personal learning goals, there are no specific requirements on the style/nature of the investigation. In particular, novelty of the report content is *not* a requirement. Possible project styles include:

(i) a broad survey of results from several papers in a particular research area (i.e., a gentle introduction to that area);

(ii) a detailed review of a technical paper, including derivation/proofs of key results and reproduction of simulations;

(iii) an application-oriented case study, applying technical course results or related results in the literature to a practical example;

(iv) an original research project, including problem formulation, analytical results, and simulation results.

Research-based students are strongly encouraged to attempt applying course concepts (or related ideas in the literature) to their thesis research.

Project Deliverables

There are three deliverables for the project.

(i) A proposal, maximum 3/4 of a page, giving a very brief description of the topic you will investigate (as if you are writing an abstract), along with what you intend to produce as project results (e.g., review, problem formulation, analytical results, simulations). The instructor will either approve the proposal or suggest appropriate modifications to the topic and/or scope. Your proposal should clearly indicate the nature of your particular project (will you do a broad survey, a technical paper review, a case study, an attempt at original research, etc.)

(ii) A (needless to say, typed) report detailing the findings of the project. The body of the report should be a **maximum of 6 pages** in standard double-column IEEE format; appending additional pages for extra figures or appendix proofs is fine. The report should follow a standard organization, such as

- Section 1: Introduction, including high-level problem description, relevant literature, summary of report content
- Section 2: Preliminaries / background material / relevant notation
- Section 3: Main content
- Section 4: Simulation results (if relevant)
- Section 5: Bibliography

The report should convey your understanding of the essential relevant ideas, in your own words, and in a concise manner. The report will be evaluated based on the following criteria:

- clarity of introduction, problem statement and associated results
- precision of statements (including any mathematical statements)
- polished presentation/writing
- evidence of independently-developed understanding

(iii) A 20 minute slide-based presentation, with 5 minutes for questions from the audience. The purpose of the presentation is to convey a bit of what you have learned to the rest of the class in a concise manner. The presentation will be evaluated based on the following criteria:

- are the problem description and presentation of results clear?
- are the visual aids effective and of high quality?
- is the quantity of presented material appropriate (not too much, not too little)?
- did the audience learn something?
- are questions handled well?

Attendance for all other student presentations is mandatory.

The report and presentation are each weighted as 50% of the project grade.

Topic elibility and suggested starting points

As a rule of thumb, if there is a graph (the kind with nodes and edges!) involved somewhere in the topic of interest, then a project on that topic is eligible. I have listed possible topics for projects below. If you do not see something of interest, I strongly encourage you to do a bit of digging and find something you are excited to learn about or work on. To avoid topic duplication, projects based on specific papers/areas below will be approved on a first-come first-serve basis, and I reserve the right to reject any project proposal that I feel is too close in scope to the core course material, or to another project which has been proposed. Note: many of the books below are available to borrow from my office or the library.

1. Distributed algorithms for solving sparse linear equations

- Mou, Liu, and Morse. A Distributed Algorithm for Solving a Linear Algebraic Equation. *IEEE Transactions on Automatic Control*, 60(11), 2015. doi: https://doi.org/10.1109/TAC.2015.2414771
- You, Tempo, and Qui. Distributed Algorithms for Computation of Centrality Measures in Complex Networks. *IEEE Transactions on Automatic Control*, 62(5), 2017. doi: https://doi.org/10.1109/TAC.2016.2604373
- Berman and Plemmons. *Nonnegative Matrices in the Mathematical Sciences.* Chap. 7.
- D. P. Bertsekas and J. N. Tsitsiklis. *Parallel and Distributed Computation: Numerical Methods.* Prentice Hall, 1989.

2. Fastest Mixing Markov Chains

- Boyd, Diaconis, and Xiao. Fastest Mixing Markov Chain on a Graph. *SIAM Review*, vol 46, issue 4, 667–689, 2006. doi: https://doi.org/10.1137/S0036144503423264
- Patel, Agharkar, and Bullo. Robotic Surveillance and Markov Chains With Minimal Weighted Kemeny Constant. *IEEE Transactions on Automatic Contol.* Vol 60, Issue 12, 2015. doi: https://doi.org/10.1109/TAC.2015.2426317

3. Synchronization

- L. Schenato and F. Fiorentin. Average TimeSynch: A consensus-based protocol for clock synchronization in wireless sensor networks. *Automatica*, 47(9):1878?1886, 2011. doi: https://doi.org/10.1016/j.automatica.2011.06.012
- R. Carli and S. Zampieri. Network clock synchronization based on the second-order linear consensus al- gorithm. *IEEE Transactions on Automatic Control*, 59(2):409?422, 2014. doi: https://doi.org/10.1109/TAC.2013.2283742
- Tang, Gao, and Kurths. Synchronization in complex networks and its application – A survey of recent advances and challenge. *Annual Reviews in Control*, vol 38, page 184–198, 2014. doi: https://doi.org/10.1016/j.arcontrol.2014.09.003
- Dörfler and Bullo. Synchronization in complex networks of phase oscillators: A survey. *Automatica*, vol 50, issue 6, pages 1539–1564, 2014. doi: https://doi.org/10.1016/j.automatica.2014.04.012

4. Network formation games

- M. O. Jackson. A survey of models of network formation: Stability and efficiency. In G. Demange and M. Wooders, editors, *Group Formation in Economics; Networks, Clubs and Coalitions.* Cambridge University Press, 2005. https://web.stanford.edu/~jacksonm/netsurv.pdf
- V. Bala and S. Goyal. A noncooperative model of network formation. *Econometrica*, 68(5):1181–1229, 2000. doi: http://dx.doi.org/10.1111/1468-0262.00155

5. Distributed optimization

- Bof, Carli, and Schenato. Is ADMM always faster than Average Consensus? *Automatica*, vol 91, pages 311–315, 2018. doi: https://doi.org/10.1016/j.automatica.2018.01.009
- Nedic and Ozdaglar. *Cooperative Distributed Multi-Agent Optimization.* url: https://wsl.stanford.edu/ITMANET/ITMANET_Publications/nedic_book.pdf

- Boyd, Parikh, Chu, Peleato and Eckstein. Distributed Optimization and Statistical Learning via the Alternating Direction Method of Multipliers. *Foundations and Trends in Machine Learning*. url: https://web.stanford.edu/~boyd/papers/pdf/admm_distr_stats.pdf. Chapter 7 in particular.
- D. P. Bertsekas and J. N. Tsitsiklis. *Parallel and Distributed Computation: Numerical Methods.* Prentice Hall, 1989.
- K. Kvaternik, J. Llorca, D. Kilper and L. Pavel. A decentralized coordination strategy for networked multiagent systems. *Allerton Conference on Communication, Control, and Computing*, Monticello, IL, 2012, pp. 41-47. doi: https://doi.org/10.1109/Allerton.2012.6483197

6. Formation control for robotic teams
   - K.-K. Oh, M.-C. Park, and H.-S. Ahn. A survey of multi-agent formation control. *Automatica*, 53: 424?440, 2015. doi: https://doi.org/10.1016/j.automatica.2014.10.022
   - Mesbahi and Egerstedt. *Graph Theoretic Methods in Multiagent Networks*. Chap 6, 7.
7. Compartmental systems
   - G. Bastin and V. Guffens. Congestion control in compartmental network systems. *Systems & Control Letters*, 55(8):689?696, 2006. doi: https://doi.org/10.1016/j.sysconle.2005.09.015
8. Collective planar motion
   - R. Sepulchre, D. A. Paley, and N. E. Leonard. Stabilization of planar collective motion: All-to-all communication. IEEE Transactions on Automatic Control, 52(5):811?824, 2007. doi: https://doi.org/10.1109/TAC.2007.898077
   - R. Sepulchre, D. A. Paley, and N. E. Leonard. Stabilization of planar collective motion with limited communication. IEEE Transactions on Automatic Control, 53(3):706?719, 2008. doi: https://doi.org/10.1109/TAC.2008.919857
9. Distributed estimation and Kalman filtering
   - Mesbahi and Egerstedt. *Graph Theoretic Methods in Multiagent Networks*. Chap 8.
   - R. Carli, A. Chiuso, L. Schenato, and S. Zampieri. Distributed Kalman filtering based on consensus strategies. *IEEE Journal on Selected Areas in Communications*, 26(4):622?633, 2008. doi: https://doi.org/10.1109/JSAC.2008.080505
   - F. S. Cattivelli and A. H. Sayed. Diffusion strategies for distributed Kalman filtering and smoothing. *IEEE Transactions on Automatic Control*, 55(9):2069?2084, 2010. doi: https://doi.org/10.1109/TAC.2010.2042987.
10. Network stability and small-gain
    - Li and Shuai. Global-stability problem for coupled systems of differential equations on networks, *Journal of Differential Equations*, vol 248, issue 1, pages 1-20, 2010. doi: https://doi.org/10.1016/j.jde.2009.09.003
    - Tengfei Liu, David J. Hill, and Zhong-Ping Jiang. Lyapunov formulation of ISS cyclic-small-gain in continuous-time dynamical networks. *Automatica*, 47(9):2088 ? 2093, 2011. doi: https://doi.org/10.1016/j.automatica.2011.06.018

- S. N. Dashkovskiy, B. S. Rüffer, and F. R. Wirth. Small gain theorems for large scale systems and construction of ISS Lyapunov functions. *SIAM Journal on Control and Optimization*, 48(6):4089?4118, 2010. doi: http://dx.doi.org/10.1137/090746483

11. Regulation and tracking in distributed control systems

    - M. Arcak. Passivity as a design tool for group coordination. *IEEE Transactions on Automatic Control*, 52(8):1380?1390, 2007. doi: http://dx.doi.org/10.1109/TAC.2007.902733
    - M. Andreasson, D. V. Dimarogonas, H. Sandberg and K. H. Johansson. Distributed Control of Networked Dynamical Systems: Static Feedback, Integral Action and Consensus. *IEEE Transactions on Automatic Control*, vol. 59, no. 7, pp. 1750-1764, July 2014. doi: https://doi.org/10.1109/TAC.2014.2309281
    - Wieland, Sepulchre, and Allgöwer. An internal model principle is necessary and sufficient for linear output synchronization. *Automatica*, vol 47, issue 5, pages 1068–1074, 2011. doi: https://doi.org/10.1016/j.automatica.2011.01.081
    - Isidori. *Lectures in Feedback Design for Multivariable Systems*. Chap 5.
    - Seyboth, Ren, and Allgöwer. Cooperative control of linear multi-agent systems via distributed output regulation and transient synchronization. *Automatica*, vol 68, pages 132–139, 2016. doi: https://doi.org/10.1016/j.automatica.2016.01.068.

12. Financial networks, stability, and risk

    - D. Acemoglu, A. Ozdaglar, and A. Tahbaz-Salehi. Systemic risk and stability in financial networks. *American Economic Review*, 105(2):564–608, 2015. doi: http://dx.doi.org/10.1257/aer.104.10.3115
    - M. Elliott, B. Golub, and M. O. Jackson. Financial networks and contagion. *American Economic Review*, 104(10):3115–53, 2014. doi: http://dx.doi.org/10.1257/aer.104.10.3115

13. Community detection and clustering in graphs

    - Fortunato. Community Detection in Graphs. *Physics Reports*, 486(3-5), pages 74-174, 2010. doi: https://doi.org/10.1016/j.physrep.2009.11.002
    - Schaeffer. Graph Clustering. *Computer Science Review* 1(1), pages 27–64, 2007. doi: https://doi.org/10.1016/j.cosrev.2007.05.001

14. Circuit and (classical) network theory

    - Anderson and Vongpanitlerd. *Network Analysis and Synthesis*. Chap. 2.
    - Chua, Desoer and Kuh. *Linear and Nonlinear Circuits*. Chap 12, 13.

15. Distributed optimal power flow

    - Yi, Hong, and Liu. Initialization-free distributed algorithms for optimal resource allocation with feasibility constraints and application to economic dispatch of power systems. *Automatica*, Volume 74, pages 259-269, 2016. doi: https://doi.org/10.1016/j.automatica.2016.08.007

- E. Dall'Anese and A. Simonetto. Optimal Power Flow Pursuit. *IEEE Transactions on Smart Grid*, vol. 9, no. 2, pp. 942-952, March 2018. doi: https://doi.org/10.1109/TSG.2016.2571982
- Various recent papers: url: https://scholar.google.ca/scholar?hl=en&as_sdt=0%2C5&q=Distributed+optimal+power+flow&btnG=

16. Large-scale dynamic system theory
    - Farina and Rinaldi. *Positive Linear Systems: Theory and Applications.*
    - Siljak. *Large-Scale Dynamic Systems: Stability and Structure.*
17. Sparse stable matrices
    - M. A. Belabbas. *Sparse Stable Matrices:* url: https://arxiv.org/pdf/1304.3478.pdf
18. Hamiltonian systems on graphs
    - A. J. van der Schaft and B. M. Maschke. Port-Hamiltonian Systems on Graphs. *SIAM Journal on Control and Optimization*, vol 51, no 2, pages 906-937, 2013. doi: https://doi.org/10.1137/110840091
19. Controllability and observability of networks
    - Liu and Barabasi. *Control Principles of Complex Networks.* url: https://arxiv.org/abs/1508.05384.
    - Pasqualetti, Zampieri, and Bullo. Controllability Metrics, Limitations and Algorithms for Complex Networks. *IEEE Transactions on Control of Network Systems*, 1(1) pp. 40–52, 2014. doi: https://doi.org/10.1109/TCNS.2014.2310254
    - Mesbahi and Egerstedt. *Graph Theoretic Methods in Multiagent Networks.* Chap 10, 12.

Useful Documents and Templates

My suggestion is to use LaTeX for producing documents and presentations which include mathematics, but I leave the decision to you for what software to use. The following may be useful to you:

- IEEE-style conference templates for MS Word and LaTeX
- Template for Powerpoint presentations
- Tutorial on LaTeX
- Tutorial on Beamer for LaTeX presentations
- Advice on giving presentations
- Advice on reading technical research papers