EE 599: Decision Making in Networked Systems
Fall 2014

Time: Tuesday and Thursday 11:00AM-12:20 PM (Tentative)
Location: TBD

Instructor: Ashutosh Nayyar

Office Hours: Friday, 10:30AM-12:30PM
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Descriptive Text: *Networked systems are ubiquitous in the technological world. Examples include sensor networks, teams of unmanned aerial vehicles, networked control systems, interconnected transportation systems, energy systems and social networks. This course will study decision-making problems in such system by using tools from probability theory, stochastic control, game theory and economics.*

Prerequisites: EE 465 or 464 or an equivalent undergraduate course on probability.

Course Overview: This course will provide a unified overview of various aspects of decision making problems in networked and decentralized systems. It will introduce students to conceptual similarities and differences between cooperative vs. competitive and static vs. dynamic systems. The course will focus on decentralized decision making in teams and the interconnections between information and decision making. It will cover recent theoretical developments in dynamic teams, decentralized control and stochastic dynamic games and their applications in problems from sensor networks, communication systems, networked control systems, decentralized control systems etc.

Intended Audience: The course is primarily intended for MS and PhD Students in Controls, Networks, Communications and Signal Processing Areas of Electrical Engineering. It should also be of interest to students in Industrial and Systems Engineering and Computer Science.

Learning Objectives: The specific objectives of the course are to:

1. Introduce students to various models of decision making problems in networked systems.
2. Equip them with basic mathematical concepts and tools used to analyze decision problems.
3. Introduce students to diverse applications and research problems in the area of decision making in networked systems.

Required Texts:
Primary:
(i) Stochastic Systems by P.R. Kumar and P. Varaiya, Prentice-Hall, 1986. [KV86]
(ii) Game theory by D. Fudenberg and J. Tirole, MIT Press, 1991. [FT91]

Supplementary:
(i) Introduction to Probability Models by Sheldon Ross, 6th ed., Academic Press, 1997. [Ross97]
(ii) Stochastic Networked Control Systems: Stabilization and Optimization under Information Constraints by S.Yuksel and T. Basar, Birkhauser 2013. [YB13]
(iii) Dynamic Programming and Optimal Control, Vol. 1 by D. Bertsekas, Athena Scientific, 2005. [DB05]
(iv) Game Theory: Analysis of Conflict by R.Myerson, Harvard University Press, 1997. [RM97].
(v) Dynamic Noncooperative Game Theory by T. Başar and G. J. Olsder. SIAM Series in Classics in Applied Mathematics Philadelphia,1999.*[Basar99]*
(vi) Competitive Markov decision processes by J. Filar and K. Vrieze, Springer, 1996. [Filar96]

Grading:
1. *Class Participation 10%*
Participation is an important component of this course and of the students' final grade. Participation will be monitored weekly and the final grade set according to the rate of participation across the class sessions.

2. *Home Works 25%*
Weekly home works, each with 4-5 problems will be given for students to sharpen their understanding of concepts introduced in class, and develop their problem-solving skills.

3. *Mid-Term Exam: 30%*
A 60 minute mid-term exam will be given in class on the last Thursday of October. The exam will test student comprehension of concepts and techniques presented to date. The instructor will have covered most of basic topics by the time of the mid-term exam.

4. Project presentation and Report (35%)
Students will be required to work on a small research project. This will involve reading 2 or more papers and writing a critical summary explaining the problem setup, prior literature, analytical approach and the results of the papers. Students shall be encouraged but not required to do some original work based on their readings. The papers and the work done shall be presented in a final project presentation in the last week of classes. The grade shall be based on the presentation in class and the written report. Suggested papers for students will include:

(i)A. Nayyar, A. Gupta, C. Langbort and T. Basar, "Common Information Based Markov Perfect Equilibria for Stochastic Games with Asymmetric Information: Finite Games," IEEE Transactions on Automatic Control, Vol. 59, No. 3, pp. 555-570, March, 2014.

(ii) V.V. Veeravalli, T. Başar, and H.V. Poor. Decentralized sequential detection with a fusion center performing the sequential test. IEEE Transactions on Information Theory, IT-39(2): 433--442, March 1993.

(iii) G. Lipsa and N. C. Martins, "Remote State Estimation With Communication Costs for First-Order LTI Systems," IEEE Transactions on Automatic Control, Vol 56, No 9, September 2011.

More examples will be added on Blackboard before the start of the course.

Statement for Students with Disabilities

Any student requesting academic accommodations based on a disability is required to register with Disability Services and Programs (DSP) each semester. A letter of verification for approved accommodations can be obtained from DSP. Please be sure the letter is delivered to the instructor (or to TA) as early in the semester as possible. DSP is located in STU 301 and is open 8:30 a.m.–5:00 p.m., Monday through Friday. The phone number for DSP is (213) 740-0776.

Statement on Academic Integrity

USC seeks to maintain an optimal learning environment. General principles of academic honesty include the concept of respect for the intellectual property of others, the expectation that individual work will be submitted unless otherwise allowed by an instructor, and the obligations both to protect one's own academic work from misuse by others as well as to avoid using another's work as one's own. All students are expected to understand and abide by these principles. *Scampus,* the Student Guidebook, contains the Student Conduct Code in Section 11.00, while the recommended sanctions are located in Appendix A: http://www.usc.edu/dept/publications/SCAMPUS/gov/. Students will be referred to the Office of Student Judicial Affairs and Community Standards for further review, should there be any suspicion of academic dishonesty. The Review process can be found at: http://www.usc.edu/student-affairs/SJACS/.

COURSE OUTLINE (by Week)

1. *Overview of Probability and Decision theory:* Conditional probability and conditional expectation, Bayes' rule, posterior beliefs, expected utility maximization.

Readings: Chapters 1-3 of [Ross97], Chapter 1 of [RM97].

2. *Team decision theory in static environments:* Models, person by person and global optimality, examples.

Readings: Chapter 2 of [YB13].

3. *Team decision theory in static environments continued:* Linear quadratic Gaussian teams.

Readings: Papers by Radner, Marschack & Radner.

4. *Decision making in dynamic environments:* State space model, Controlled Markov chain model, Markov policies and their costs.

Readings: Chapter 2 and 4 of [KV86].

5. *Overview of dynamic programming:* Fundamentals of dynamic programming, perfect and partial observation models, linear quadratic Gaussian control.

Readings: Chapter 6, 7 of [KV86].

6. Dynamic teams: Models, person by person vs. global optimality, examples from decentralized control, networked control systems, sensor networks and communication systems.
Readings: Chapter 3 of [YB13]

7. *Classical and Quasi-classical information structures:* Partially nested information structures, reduction to static teams, sequential decomposition, optimality of linear strategies.
Readings: Chapter 3 of [YB13], Papers by Witsenhausen, Ho and Chu.

8. *Non-classical information structures:* Witsenhausen counterexample, Generalized Gaussian test channel, signaling in teams, reduction to static teams and loss of convexity.
Readings: Papers by Witsenhausen, Bansal and Basar, Mahajan *et al.*

9. *Person by person methods in dynamic teams:* Conceptual formulation, implications, limitations, examples from sensor networks, communication and decentralized control.
Readings: Papers by Ho and Chu, Mahajan and Teneketzis.

MID TERM EXAM

10. Designer based methods for dynamic teams: Conceptual formulation, Witsenhausen's standard form, sequential decomposition, examples.
Readings: Papers by Witsenhausen, Mahajan and Teneketzis.

11. Common information in dynamic teams: Common knowledge, partial control strategies, coordinator based methods, examples.
Readings: Papers by Aumann, Nayyar *et al.*

12. Decentralized control as norm optimization: Quadratic invariance, Youla parametrization, reduction to constrained convex program.
Readings: Papers by Rotkowitz and Lall, Lessard and Lall.

13. From teams to games: Model, equilibrium concepts, examples, repeated and dynamic games.
Readings: Chapter 3 and 5 of [FT91].

14. Common information and backward induction in dynamic games: Markov perfect equilibria, common information based equilibria, backward inductive methods.
Readings: Chapter 6 of [Basar99], papers by Nayyar and Gupta.

15. Project Presentations

FINAL PROJECT REPORTS DUE