<u>**Network Control Systems**</u>
EML 6934, Section 472D
Fall 2021**,** M W ~~F~~, Period 7, 1:55 PM - 2:45 PM
MCCB 1108

Modifications to this syllabus may be required during the semester. Any changes will be posted on Canvas.

Professor
- Matthew Hale, Ph.D.
- Email: matthewhale@ufl.edu

Office Hours
- Monday 3:30 – 4:30 PM
- Wednesday 3:30 – 4:30 PM
- Held on Zoom at: https://ufl.zoom.us/j/99258522443?pwd=VysySXFNa0M1Q2hoZUhvSjB3TTBHUT09

Lectures
- **This class will use a <u>flipped</u> classroom methodology.** Lectures will be pre-recorded and posted to Canvas at 9am on Monday, Wednesday, and Friday. This is to accommodate those who are unable to attend class, e.g., due to being withheld from campus, or those uncomfortable doing so. Our class time will be used as an optional recitation time to solve problems, answer questions, and discuss research in the area of network control systems. These will proceed similar to office hours, in that there will not be formal lectures. As noted above, office hours will be held exclusively on Zoom. These steps are taken to ensure the fulfillment of learning objectives in the event that students are unwilling or unable to attend class (see below for course objectives and outcomes).
- In light of the flipped methodology, and to ensure that the time requirement of this course remains manageable, only two lectures per week will be in person. That is, **we will be in the classroom during class time on Mondays and Wednesdays, but not Fridays.**
- **You are expected to wear a mask at all times in the classroom.**
- On Mondays and Wednesdays, if the professor is more than 15 minutes late, students are permitted to leave with no consequences. Similarly, on Mondays and Wednesdays, if no students are present, the professor will leave after 15 minutes.

Course Objectives
By the end of the course, you should be able to do the following:
- Model multi-agent networks as graphs
- Use linear algebra to assess algebraic and spectral graph properties
- Analyze the stability of network control systems
- Design local interaction protocols that give rise to desired global behaviors
- Apply graph-theoretic principles to problems in sensing and estimation
- Relate engineered systems to the natural world through the lens of network science

Course Pre-Requisites / Co-Requisites
- EML 5311 – Control System Theory
- Graduate standing

Textbooks and Software
- There is not a required textbook for this class. The books below are optional:
  1. *Graph Theoretic Methods in Multi-Agent Networks*, M. Mesbahi and M. Egerstedt, Princeton University Press, 2010.
  2. *Lectures on Network Systems*, F. Bullo. Free at: http://motion.me.ucsb.edu/book-lns/
- Assignments in this class will require access to MATLAB

Important Dates
- Homework dates will be announced in class. There will be five total.
- October 11th: Midterm to be held online during class time
- December 15th: Final Exam, 10am-12pm (also online)

Evaluation of Grades and Grading Policy

     Evaluation Mechanism on a Percent Basis

Homework	33.33%
Midterm	33.33%
Final	33.33%

Course Schedule (Approximately), with readings from Mesbahi/Egerstedt

1	Course Introduction, Introduction to Network Control Systems	Chapter 1
2	The Rendezvous Problem	Chapter 1
3-5	Algebraic Graph Theory	Chapter 2
6	Graph Connectivity and Robustness	Chapter 2
7	Return to Rendezvous	Chapter 3
8	The Consensus Protocol	Chapter 3

Approximate End of Coverage for Homework 1

9	Discrete-Time Consensus	Chapter 3
10	Directed Consensus	Chapter 3
11	Switching Consensus	Chapter 4
12-13	Lyapunov Stability with Switching Networks	Chapter 4,7
14-15	Weighted Protocols	Chapter 6

Approximate End of Coverage for Homework 2

16	Energy-Based Protocol Design	Chapter 6
17	Biological Connections	
18	The Synchronization Problem and Kuramoto Model	Chapter 4

End of Coverage for Midterm Exam

19	Midterm Review	
20	Midterm (during class time on October 11th)	
21-22	Formation Control	Chapter 6

Approximate End of Coverage for Homework 3

23	Graph Rigidity	Chapter 6
24	Graph Persistence	Chapter 6
25	The Assignment Problem	Chapter 6
26-28	Leader-Follower Control	Chapter 10

Approximate End of Coverage for Homework 4

Approximate End of Coverage for Homework 5

<u>Homework</u>

Homework will be graded on a scale from 1-5. A grade of 5 indicates that all problems have been solved without any mistakes (of any size). A grade of 4 indicates that solutions show a correct understanding on a conceptual level and are generally mathematically correct, modulo a small number of minor mistakes. A grade of 3 indicates numerous mistakes and/or a key conceptual misunderstanding. A grade of 2 indicates multiple significant conceptual misunderstandings. A grade of 1 reflects that very little has been done correctly. Homework solutions will be posted to Canvas after the due date.

<u>Grade Corrections</u>

Grade corrections must be submitted via email within 3 business days of the grade posting.

<u>Final Grade</u>

The final grade will be calculated by the following table. The student is guaranteed to earn the grade point shown in the table based on their percent earned grade. For example, if a student earns 88.60% (Percent Grade Earned %GE = 88.60) then their grade point will be 3.33 (B+). %GE are rounded to the hundredths decimal place. For example, if a student earns 79.995% (Percent Grade Earned %GE = 79.995) it will be rounded up to 80.00%, and their grade will be 2.67 (B-). Higher grades can be assigned if the professor elects to curve the entire class. Particularly inquisitive and curious students may be given higher grades at the discretion of the professor.

Table 1. Grading Table. *%GE = Percent Grade Earned.*

Percentage Range	Grade Point
$93.33 \leq \%GE < 100.00 \Longrightarrow$ A	4.00
$90.00 \leq \%GE < \ 93.33 \Longrightarrow$ A-	3.67
$86.67 \leq \%GE < \ 90.00 \Longrightarrow$ B+	3.33
$83.33 \leq \%GE < \ 86.67 \Longrightarrow$ B	3.00
$80.00 \leq \%GE < \ 83.33 \Longrightarrow$ B-	2.67
$76.67 \leq \%GE < \ 80.00 \Longrightarrow$ C+	2.33
$73.33 \leq \%GE < \ 76.67 \Longrightarrow$ C	2.00
$70.00 \leq \%GE < \ 73.33 \Longrightarrow$ C-	1.67
$66.67 \leq \%GE < \ 70.00 \Longrightarrow$ D+	1.33
$63.33 \leq \%GE < \ 66.67 \Longrightarrow$ D	1.00
$60.00 \leq \%GE < \ 63.33 \Longrightarrow$ D-	0.67
$00.00 \leq \%GE < \ 60.00 \Longrightarrow$ E	0.00

Relation to Program Outcomes (ABET):

Outcome	Coverage[*]
1. An ability to identify, formulate, and solve engineering problems by applying principles of engineering, science, and mathematics.	High
2. An ability to apply both analysis and synthesis in the engineering design process, resulting in designs that meet desired needs.	Medium
3. An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.	
4. An ability to communicate effectively with a range of audiences	
5. An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.	
6. An ability to recognize the ongoing need for additional knowledge and locate, evaluate, integrate, and apply this knowledge appropriately.	Low
7. An ability to function effectively on teams that establish goals, plan tasks, meet deadlines, and analyze risk and uncertainty	

[*]Coverage is given as high, medium, or low. An empty box indicates that this outcome is not covered or assessed in the course.

Students Requiring Accommodations

Students with disabilities requesting accommodations should first register with the Disability Resource Center (352-392-8565, https://www.dso.ufl.edu/drc) by providing appropriate documentation. Once registered, students will receive an accommodation letter which must be presented to the instructor when requesting accommodation. Students with disabilities should follow this procedure as early as possible in the semester.

Course Evaluation

Students are expected to provide feedback on the quality of instruction in this course by completing online evaluations at https://evaluations.ufl.edu/evals. Evaluations are typically open during the last two or three weeks of the semester, but students will be given specific times when they are open. Summary results of these assessments are available to students at https://evaluations.ufl.edu/results/.

University Honesty Policy
UF students are bound by The Honor Pledge which states, "We, the members of the University of Florida community, pledge to hold ourselves and our peers to the highest standards of honor and integrity by abiding by the Honor Code. On all work submitted for credit by students at the University of Florida, the following pledge is either required or implied: "On my honor, I have neither given nor received unauthorized aid in doing this assignment." The Honor Code (https://sccr.dso.ufl.edu/policies/student-honor-code-student-conduct-code/) specifies a number of behaviors that are in violation of this code and the possible sanctions. Furthermore, you are obligated to report any condition that facilitates academic misconduct to appropriate personnel. If you have any questions or concerns, please consult with the instructor or TAs in this class.

Commitment to a Safe and Inclusive Learning Environment
The Herbert Wertheim College of Engineering values broad diversity within our community and is committed to individual and group empowerment, inclusion, and the elimination of discrimination. It is expected that every person in this class will treat one another with dignity and respect regardless of gender, sexuality, disability, age, socioeconomic status, ethnicity, race, and culture.

If you feel like your performance in class is being impacted by discrimination or harassment of any kind, please contact your instructor or any of the following:
• Your academic advisor or Graduate Program Coordinator
• Robin Bielling, Director of Human Resources, 352-392-0903, rbielling@eng.ufl.edu
• Curtis Taylor, Associate Dean of Student Affairs, 352-392-2177, taylor@eng.ufl.edu
• Toshikazu Nishida, Associate Dean of Academic Affairs, 352-392-0943, nishida@eng.ufl.edu

Software Use
All faculty, staff, and students of the University are required and expected to obey the laws and legal agreements governing software use. Failure to do so can lead to monetary damages and/or criminal penalties for the individual violator. Because such violations are also against University policies and rules, disciplinary action will be taken as appropriate. We, the members of the University of Florida community, pledge to uphold ourselves and our peers to the highest standards of honesty and integrity.

Student Privacy
There are federal laws protecting your privacy with regards to grades earned in courses and on individual assignments. For more information, please see: https://registrar.ufl.edu/ferpa.html

Campus Resources:

Health and Wellness

U Matter, We Care:
Your well-being is important to the University of Florida. The U Matter, We Care initiative is committed to creating a culture of care on our campus by encouraging members of our community to look out for one another and to reach out for help if a member of our community is in need. If you or a friend is in distress, please contact umatter@ufl.edu so that the U Matter, We Care Team can reach out to the student in distress. A nighttime and weekend crisis counselor is available by phone at 352-392-1575. The U Matter, We Care Team can help connect students to the many other helping resources available including, but not limited to, Victim Advocates, Housing staff, and the Counseling and Wellness Center. Please remember that asking for help is a sign of strength. In case of emergency, call 9-1-1.

Counseling and Wellness Center: http://www.counseling.ufl.edu/cwc, and 392-1575; and the University Police Department: 392-1111 or 9-1-1 for emergencies.

Sexual Discrimination, Harassment, Assault, or Violence
If you or a friend has been subjected to sexual discrimination, sexual harassment, sexual assault, or violence contact the **Office of Title IX Compliance**, located at Yon Hall Room 427, 1908 Stadium Road, (352) 273-1094, title-ix@ufl.edu

Sexual Assault Recovery Services (SARS)
Student Health Care Center, 392-1161.

University Police Department at 392-1111 (or 9-1-1 for emergencies), or http://www.police.ufl.edu/.

Academic Resources

E-learning technical suppor*t*, 352-392-4357 (select option 2) or e-mail to Learning-support@ufl.edu. https://lss.at.ufl.edu/help.shtml.

Career Resource Center, Reitz Union, 392-1601. Career assistance and counseling. https://www.crc.ufl.edu/.

Library Support, http://cms.uflib.ufl.edu/ask. Various ways to receive assistance with respect to using the libraries or finding resources.

Teaching Center, Broward Hall, 392-2010 or 392-6420. General study skills and tutoring. https://teachingcenter.ufl.edu/.

Writing Studio, 302 Tigert Hall, 846-1138. Help brainstorming, formatting, and writing papers. https://writing.ufl.edu/writing-studio/.

Student Complaints Campus*:*
https://www.dso.ufl.edu/documents/UF_Complaints_policy.pdf.

On-Line Students Complaints*:* http://www.distance.ufl.edu/student-complaint-process.

COVID-19

- You are expected to wear approved face coverings at all times during class and within buildings even if you are vaccinated.
- If you are sick, stay home and self-quarantine. Please visit the UF Health Screen, Test & Protect website about next steps, retake the questionnaire and schedule your test for no sooner than 24 hours after your symptoms began. Please call your primary care provider if you are ill and need immediate care or the UF Student Health Care Center at 352-392-1161 (or email covid@shcc.ufl.edu) to be evaluated for testing and to receive further instructions about returning to campus.
- If you are withheld from campus by the Department of Health through Screen, Test & Protect, you are not permitted to use any on campus facilities. Students attempting to attend campus activities when withheld from campus will be referred to the Dean of Students Office.
- UF Health Screen, Test & Protect offers guidance when you are sick, have been exposed to someone who has tested positive or have tested positive yourself. Visit the UF Health Screen, Test & Protect website for more information.
- Please continue to follow healthy habits, including best practices like frequent hand washing. Following these practices is our responsibility as Gators.