# 

# ECSE 4500/6500 Distributed Systems

# Syllabus - Spring 2021

## Course Information

Time: Mondays and Thursdays 10:10 am to 11:30 am

Place: online

Class website: Piazza

## Prerequisites or Other Requirements

Familiar with one programming language either Matlab or Python (preferred).

It is recommended to first take courses in mathematical optimization, linear algebra and real analysis.

## Instructor

Prof. Tianyi Chen

Office Location: JEC 6036

Office Hours: Mondays at 4 pm – 5 pm, or by appointment

Email: [chent18@rpi.edu](mailto:chent18@rpi.edu) --- the best way to contact me is through email.

TA: XXX Email: XXX

TA office hour: XXX

## Course Description

This course is **neither about hardware implementation nor design of distributed systems**. This is a course about **algorithms and simulations** of parallel and distributed optimization. The course covers parallel and distributed optimization algorithms and their analyses that are suitable for large-scale and distributed problems arising in machine learning and signal processing.

## Student Learning Outcomes

After taking the course, **undergraduate** students are expected to know:

1. how to formulate a distributed optimization problem from real-world learning, estimation, and control problems in distributed systems;
2. how to implement numerically stable algorithms to solve real-world engineering problems in distributed systems;
3. how to qualitatively evaluate the efficiency of a distributed algorithm for various applications in distributed systems.

In addition to the above, **graduate** students are also expected to know:

1. how to estimate the per-iteration complexity, namely, counting the number of arithmetic operations of a distributed optimization algorithm;
2. how to design and modify numerically stable algorithms to solve real-world engineering problems for various applications in distributed systems.

## Course Content

1. Optimization basics and complexity measures
2. Basic machine learning models
3. Parallel and distributed architectures
4. Synchronization issues in parallel and distributed algorithms
5. Communication aspects of parallel and distributed systems
6. Synchronous distributed algorithms
   1. Distributed gradient descent
   2. Distributed/local stochastic gradient descent
   3. Distributed variance reduced stochastic gradient
7. Synchronous decentralized algorithms
8. Decentralized gradient descent
9. Decentralized ADMM
10. Decentralized stochastic gradient descent
11. Asynchronous distributed and decentralized algorithms
12. Decentralized algorithms with time-varying topology\*
13. Applications in machine learning, signal processing and control

1) Federated learning

2) Distributed reinforcement learning

3) Distributed power system state estimation

4) Distributed parameter estimation in sensor networks

5) Decentralized model-based tracking\*

Items with “\*” will be covered if schedule allows.

## Optional References

1. Dimitri P. Bertsekas and John N. Tsitsiklis, “[*Parallel and Distributed Computation: Numerical Methods*](http://web.mit.edu/dimitrib/www/pdc.html),” Athena Scientific, 2015.

(Very comprehensive and in-depth. May be too dense/sophisticated for new students.)

1. Stephen Boyd, et. al., “[*Distributed Optimization and Statistical Learning via the Alternating Direction Method of Multipliers*](http://www.nowpublishers.com/article/Details/MAL-016),” Found. and Trends Machine Learning, 2011.

(Easy to follow in most part, focus on ADMM.)

1. Ernest Ryu and Wotao Yin, “*A First Course in Large-Scale Optimization*,” preprint, 2019.

(Easy to follow in most part, modern approaches.)

1. Guanghui Lan, *“*[*Lectures on Optimization Methods for Machine Learning*](http://pwp.gatech.edu/guanghui-lan/wp-content/uploads/sites/330/2019/08/LectureOPTML.pdf),” preprint, 2019.

(Very comprehensive, modern approaches.)

1. Georgios B. Giannakis, et. al., “[Decentralized learning for wireless communications and networking](https://arxiv.org/pdf/1503.08855.pdf),” Springer, New York, 2015 (Focus on wireless communication, networking and power system applications)

## Grading Criteria

One term exam (focus on basics) 24%

Homework (total 4, ~ per month) 32%

Class attendance (two random quizzes) 4%

Course project (presentation + report) 40%

**ECSE 4500 – group project (2-3 students)**. It can be either theoretic or experimental, with approval from the instructor. You are encouraged to combine your current research with your term project.

**ECSE 6500 - individual project**. It can be either theoretic or experimental, with approval from the instructor. You are encouraged to combine your current research with your term project.

## Other Course Policies

**Homework Problems:**

1. Late homework will not be accepted.
2. All homework assignments are to be completed on your own. You are allowed to consult with other students in the current class regarding the conceptualization of the problem and possible methods of solution, but you may not share details, whether in the form of scrap work, or final write-ups. You may not copy solutions from anyone or any source.
3. You may not knowingly provide your work to be copied.

**Attendance Policy:** While class attendance is not mandatory, regular class attendance is important for maximum learning effectiveness and it significantly improves performance on graded course deliverables.

**Term Exams Grading Assessment:** Shortly after each Term Exam, the class averages and standard deviations will be announced in class. This information will enable students to approximate their class standing and expected course grade.

**Submission Policy and Absences:**

An approved absence is one that has been approved following Rensselaer’s rules and procedures, and should be documented, typically via a letter from the dean’s office, and emailed beforehand to the instructor. A missed exam due to an unexpected emergency should be communicated in writing as soon as possible.

1. All in-class activities are due in class after the allotted time expires. No late activities are accepted. In case of a valid excuse, a missed activity grade will not be taken into account in computing the average grade of activities, as long as there is at least one submitted activity. Otherwise a grade of zero is given for a late/missing activity.
2. Late submissions are not accepted. In case of a valid excuse, a missed homework grade will not be taken into account in computing the average grade of homeworks, as long as there is at least one submitted homework.
3. All term exams are due at the due date/time. In case of a valid excuse, a make-up exam will be held at a time that is to be agreed with the instructor. The make-up exam has to be completed within one week of the missed exam date.

## Academic Integrity

1. Student-teacher relationships are built on trust. For example, students must trust that teachers have made appropriate decisions about the structure and content of the courses they teach, and teachers must trust that the assignments that students turn in are their own. The Rensselaer Handbook of Student Rights and Responsibilities defines various forms of Academic Dishonesty and you should make yourself familiar with these.
2. In this class, all assignments (exam, homework or in-class activity) that are turned in for a grade must represent the student’s own work completed independently. In cases where help was received, or teamwork was allowed, a note on the assignment should indicate the nature of the collaboration and the names/identities of the collaborators.
3. **Mobile Devices:** All mobile devices (cell/smart phones, computers, pagers, etc.) must be stored securely away during exam. Use of (or ANY interaction with) a mobile device during an exam without explicit permission of the instructor will be interpreted as the illicit transfer of exam data, will be considered an act of cheating and will be treated as such.
4. Any incident of violation of this policy on an exam/assignment will result in at least a penalty of 0 for the first incidence (depending on the gravity), and a class grade of F for a repetition or a straight F grade even for first violation depending on the gravity. A grade of F due to violation(s) will also be reported to the Dean of Students.