CSCE-637 Complexity Theory

Fall 2020

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Office Hours: TR 1:30 pm–3:00 pm

COURSE PROJECT

(Due December 1, 2020)

Overview. This course is research oriented. Therefore, an important component of the course is the participation in course research, which consists of reading research papers and working on course projects. The course project will provide students with opportunities to practice what they learn from the course and try to derive new research results interesting in the area.

It is advised that students combine the two parts of the research into an integrated project. Therefore, a student will

1. identify a research topic that is interesting to you (it will be the best if you pick a research topic that is directly related to your thesis research);

2. pick a significant research paper on the topic, have an in-depth reading, and write a detailed report on the paper based on your understanding (the paper reading report should be at least 4 printed pages long, single-spaced); and

3. do further research based on the paper and your understanding. This can be either extending or enhancing the research given in the paper, making observations on the paper, pointing out errors or confusions found in the paper, or discussing possible (or impossible) improvements over the results given in the paper. A report on the course project should be at least 8 printed pages long, single-spaced.

It is also fine if you decide not to couple the paper reading and research project. In this case, you also need to submit a paper reading report of at least 4 pages, and a project report of at least 8 pages.

Research Proposal. Students should submit a proposal **no later than November 5**, to propose the paper they are going to read and the topic of their research project, plus a brief explanation on the significance of the research. The proposals should get approved by the instructor, based on their depth and relevance to the course. Students are encouraged to submit their proposals as early as they can so that they can start working on the approved research projects as early as possible.

Suggested Research Topics.

The following are some suggested research topics that students may want to consider for their course project. This list is not exclusive. Students may pick other topics based on their own interests and the relevance to their current research. However, the topics must be related to computational complexity theory

1. Study of lower bounds on circuit complexity. This is a very interesting and classical research topic, with recent progresses. You may start with the paper by Find, et al., or the paper by Williams, given in the course webpage.

2. Study of the computational models based on circuit families. In particular, you can study parallel complexity theory based on circuit families. Start with the paper by Borodin, et al. given in the course webpage.

3. Study of space-bounded computation. You can start with Immerman-Szelepcsenyi Theorem. After this breakthrough, there have been pretty much progresses, in particular in the study of space-bounded deterministic computation.

4. Further study of the polynomial-time hierarchy. This is a classical topic.

5. Study of probabilistic computation. Here both the study of randomized algorithms and probabilistic complexity theory are extremely interesting.

6. Study complexity theoretical issues for approximation algorithms. The course will discuss this direction, but it might be too late for your course project. Therefore, if you want to pick this topic, you may need to start by self-study.

7. Parameterized complexity theory. The situation is similar to that of approximation algorithms: the course will discuss this direction, but the discussion might be too late for your course project, and you need to start earlier by yourself.

8. Fine-grained complexity theory and applications. This is a more recent research direction in complexity theory.

9. Complexity issues in cryptography. Complexity theory has been an important topic in the study of cryptography. You may start with the paper by Agrawal, et al. given in the course webpage.

10. Complexity theory and quantum computing. Many interesting and new topics are there in this area.

11. Complexity theory and AI and deep learning. This relates complexity theory to the currently most popular research areas.

12. Study of (practical) complexity theory. Here you may pick a problem of practical importance, and study its intractability (e.g., NP-hardness). For this study, your paper reading can be on a paper from a less theoretical area, but with practical importance and potential theoretical depth.

Grading

- Paper reading: 30% of the course grade.
  The grade will be based on the paper reading report.

- Research project: 45% of the course grade.
  The grade will be based of the depth and quality of the research, and the presentation of the project report.