Syllabus: Algorithms on Digraphs
Winter 2018–9

Updated: October 30, 2018

Basic Information

Important People

- Saeed Amiri (Lecturer)
  Office: Campus E1 4, Room 312
  Office Hours: Tuesday, 14:00–15:00
  Email: `samiri@mpi-inf.mpg.de`
- Eunjin Oh (Teaching Assistant & Guest Lecturer)
  Office: Campus E1 4, Room 317
  Email: `eoh@mpi-inf.mpg.de`
- Will Rosenbaum (Lecturer)
  Office: Campus E1 4, Room 319
  Office Hours: Thursday, 15:00–16:00
  Email: `wrosenba@mpi-inf.mpg.de`

Meetings

- Lectures will be held on Mondays from 10:00 to 12:00 in E1 4, room 024 starting on 22 October.
- Problem solving sessions will be held every other Wednesday (on the even-numbered weeks listed below), from 14:00 to 16:00 in E1 4, room 023.

Course Description

Algorithmic graph theory is one of the oldest and best-studied subjects in computer science. The classical theory assumes edges, i.e., connections between nodes, are symmetric: if there is an edge connecting v and u, then the same edge connects u to v. However, in many physical systems, connections are inherently asymmetric. Such systems are best modeled by directed graphs (digraphs). Unfortunately, many problems that are straightforward to solve for undirected graphs become difficult or intractable for digraphs. In many cases, methods for dealing with digraphs are intrinsically different from the corresponding methods for undirected graphs.

In this course we will cover some recently developed techniques for designing algorithms on digraphs. We will focus on three main topics:

1. Separators and cuts, with applications to the feedback vertex set and multiway cut problems.
2. Routing problems such as the disjoint paths problem, finding long paths, and packet scheduling and routing.

3. Structural properties of digraphs, in particular directed treewidth.

Additionally, there will be guest lectures by Eunjin Oh, who will discuss related problems arising in computational geometry.

The course will assume a background in the fundamentals of graph theory and the analysis of algorithms consistent with [4]. Specifically, we will assume familiarity with the following topics (along with their corresponding sections in [4]):

- Growth of functions and asymptotic notation (Ch. 3)
- Probabilistic analysis of randomized algorithms (Ch. 5)
- Dynamic programming (Ch. 15)
- Greedy algorithms (Ch. 16)
- Graph algorithms (Ch. 22–24)
- NP-completeness (Ch. 34)
- Discrete math and probability (Appendices A–C)

We will not presume any specific experience with directed graphs.

Homework & Evaluation

Student evaluation will be based on homework/participation (25% each) and an oral final exam (50%).

Homework (25%) There will be roughly one homework assignment for each week of class. Homework will be due on Fridays, typically of the week following the lecture. **Please hand in assignments by 16:00 on the due date.** Collaboration on homework assignments is encouraged! Students may work on the assignments in small groups (2–4 people) and the group may submit a single write-up.

Participation (25%) In order to receive full credit, students must actively participate in the TA session. This participation may consist of presenting a recap of lecture material, presenting solutions to old assignments, or collaborating in solving problems for forthcoming assignments.

Final Exam (50%) Oral final exams will take place on **15 February, 2019**. Individual exam times will be scheduled near the end of the semester. At that time, students will be provided with a list of topics and suggested problems that will encompass the scope of the exam.

Lecture Schedule

Week	Date	Lecturer	Topic
0	16.10	—	No Lecture
1	22.10	Saeed	Introduction; Hamiltonian cycles and feedback vertex set in tournaments
2	29.10	Will	Color coding [5] Section 5.2, and long directed cycles [8]
3	5.11	Saeed	Directed treewidth [2] Chapter 9
4	12.11	Will	Disjoint paths [2] Chapter 9
5	19.11	Saeed	Erdös-Posa property [2] Chapter 9, and [1]
6	26.11	Saeed	Erdös-Posa property [1]
7	3.12	Will	Static routing [6]
8	10.12	Will	Static and dynamic routing [6, 7]
9	17.12	Will	Dynamic routing [7]
10	7.1	Saeed	Important separators [3]
11	14.1	Saeed	Important separators [3]
12	21.1	Will	Directed grids and planar graphs[2]
13	28.1	Eunjin	Geometric graphs
14	4.2	Eunjin	Geometric graphs

Oral Final Exam: 15 February, by appointment.

Source Materials

[1] Saeed Akhoondian Amiri, Ken-Ichi Kawarabayashi, Stephan Kreutzer, and Paul Wollan. The erdos-posa property for directed graphs. *arXiv preprint arXiv:1603.02504*, 2016.

[2] Jrgen Bang-Jensen and Gregory Gutin. *Classes of Directed Graphs*. Springer Publishing Company, Incorporated, 1st edition, 2018.

[3] Rajesh Chitnis, Marek Cygan, Mohammadtaghi Hajiaghayi, and Dániel Marx. Directed subset feedback vertex set is fixed-parameter tractable. In Artur Czumaj, Kurt Mehlhorn, Andrew Pitts, and Roger Wattenhofer, editors, *Automata, Languages, and Programming*, pages 230–241, Berlin, Heidelberg, 2012. Springer Berlin Heidelberg.

[4] T.H. Cormen, T.H. Cormen, C.E. Leiserson, R.L. Rivest, Massachusetts Institute of Technology, C. Stein, Inc Books24x7, MIT Press, and McGraw-Hill Publishing Company. *Introduction To Algorithms*. MIT electrical engineering and computer science series. MIT Press, 2001.

[5] Marek Cygan, Fedor V Fomin, Łukasz Kowalik, Daniel Lokshtanov, Dániel Marx, Marcin Pilipczuk, Michał Pilipczuk, and Saket Saurabh. *Parameterized Algorithms*. Springer, 2015.

[6] F. T. Leighton, Bruce M. Maggs, and Satish B. Rao. Packet routing and job-shop scheduling in o(congestion+dilation) steps. *Combinatorica*, 14(2):167–186, Jun 1994.

[7] Boaz Patt-Shamir and Will Rosenbaum. The space requirement of local forwarding on acyclic networks. In *Proceedings of the ACM Symposium on Principles of Distributed Computing*, PODC '17, pages 13–22, New York, NY, USA, 2017. ACM.

[8] Meirav Zehavi. A randomized algorithm for long directed cycle. *Inf. Process. Lett.*, 116(6):419–422, June 2016.