TheoryPrep

Summer 2020

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Course Description

TheoryPrep is a completely free (there is no cost for the course and no required materials to purchase) Harvard CS resource by students for students. A common CS series of 121 and 124 is substantially more mathematically intensive than CS 50/51, and for students with less mathematical maturity, this can be a large step up. TheoryPrep is a summer course that aims to help students prepare for these courses so they can get the most out of them. It has some overlap with CS20, with additional topics we think are particularly important for 121/124. Our team is composed of former and future CS TFs (especially for CS 20, 121, and 124), and we want to use our experiences learning and teaching in 121/124 to help prepare you for them. Going in unprepared, these classes can be extremely difficult, but with some mathematical background, we believe you'll be able to not only learn the material but appreciate how cool it is!

Materials

All course books and materials will be available on the website. There will be no financial costs to the student.

Course Focus

The course will primarily teach *skills*, not content. Our goal is to help you develop ways of thinking and methods of approaching complex problems. You will learn to re-frame complex problems in formal language, break them down into manageable parts, and prove each part. There are some important content prerequisites for CS 121/124, which we will cover, but even in these weeks the focus will be on using proofs about this content to develop *proof-writing and reading skills*. The instructors have chosen to focus on methods because we feel this is the best preparation for Theoretical CS.

The first four weeks of this course cover important foundations for discrete math and writing mathematical proofs. Our goal is to transform proofs from something that may seem foreign

and arcane into a series of techniques and tools that you can apply to comfortably argue about mathematical objects. We'll do this by introducing the most commonly used discrete math objects and a variety of proof techniques, and then helping you hone your proof skills via practice. The first half of the course is also designed to help you understand how proof-based math is different from computation-based math, and we aim to give you an appreciation the subject. The last four weeks of the course take these skills you've built and prepare you for 121/124 in two ways. First, we focus on topics and techniques that are often used in the courses (for example, we study reductions, which are used in the majority of proofs in the second half of 121). Second, we present and help you construct substantially longer proofs, which is an important skill for 121/124. Having some experience and strategies for reading long definitions and proofs can make learning a new topic exciting insights instead of drudgerous memorization!

Logistics

What is the Time Commitment?

The course will take approximately 6 hours a week for 8 weeks, running from June 1 to July 26. We explain below how this time will be spent.

Readings and Videos

Each week there will be approximately 1 hour of video content produced by the instructors covering important concepts for that weeks material and approximately 1 hour of assigned readings. The videos will cover content at a high level, focusing on motivating the week's material and providing intuition. The readings will cover the equally important details (additional definitions and concepts) that will be important for the problem sets. We advise you to begin with the videos to get a big picture before moving onto the reading (having seen motivation will also make the experience of learning the definitions and fundamentals more enjoyable).

Problem Sets

Problem Sets will be collections of practice problems and conceptual questions aimed at helping you to hone in on important concepts from that week and develop the key problem solving skills. Hopefully the problems do not feel annoying or useless; we really, really want you to feel like doing each problem helps you learn something important. We will try our absolute hardest to ensure that the problems are interesting and none of the problems end up feeling like busywork.

Problem Sessions

Each week there will be multiple Zoom sessions that you can join to work on the assignments with others (we expect students to attend 4 hours of these sessions total per week and design the problem sets such that with a little outside work, this will be sufficient to finish them). We advise students to start the problem sets on their own because doing problems on your own can be an educational experience, but we also recognize that collaboration is a great way to learn, especially for proofs.

The main goal for these sessions is to allow students to work on the assignments together. Each session will have one or more course staff members present to help with problems as well (you can also use this time to help clarify material you didn't understand from videos/readings). We hope these problem sessions will be a fun place to meet others in the Harvard CS community and stay connected!

There will be a Gradescope submission portal for each assignment and a recommended submission date such that we can provide feedback on assignment problems to those who submit them. The feedback will be constructive and hopefully useful for building your skills. There will be optional opportunities to re-submit work in response to Instructor feedback because the process of learning from your mistakes is often self-edifying!

Website

The website will be the repository for all materials and announcements for the course. Please try to refer to it often, as it will be updated regularly with course materials, videos, assignments, Zoom links etc.

Questions

Please email theoryprep@gmail.com with any and all questions or concerns regarding TheoryPrep.

Schedule and weekly learning goals

Week 01, 06/01 - 06/05: Introduction to Proofs and Basic Concepts

- Quantifiers and Using Them to Express Logical propositions and Mathematical Claims ($\forall, \exists$ etc.)
- Sets and Their Uses ($\mathbb{N}, \mathbb{Z}$ etc.)
- Basic Proof Ideas and Concepts

Week 02, 06/08 - 06/12: Additional Proof Techniques and Formal Logic

- Proof by Contrapositive (and a presentation of formal logic)
- Proof by Induction
- Proof by Exhaustion

Week 03, 06/15 - 06/19: Measuring Cardinality and Motivating Definitions

- Functions
- Infinite Sets, Countability
- What is the Point of a Definition?

Week 04, 06/22 - 06/26: Graph Theory

- Graph Theory Basics and Properties
- Colorings
- Bipartite Graphs

Week 05, 06/29 - 07/03: Tackling Harder Problems (CS 121/124 Prep)

- How to Read a Definition Critically
- How to Read a Complex Proof
- How to Write Longer Proofs

Week 06, 07/06 - 07/10: Reductions (CS 121 Prep)

- Polynomial Time Computability
- Computability Reductions
- Uncomputability Reductions

Week 07, 07/13 - 07/17: Asymptotics (CS 124 Prep)

- Asymptotics and Recurrence Relations
- Inductive Sets and The Inductive Reasoning Principle

Week 08, 07/20 - 07/24: Algorithmic Analysis (CS 124 Prep–exact topics subject to change)

- Algorithms on Graphs
- MST algorithms