Final Paper Topics Ideas

For your final paper, you must choose a topic either from the list below or that you suggest by yourself. Your topic should have some relationship to the topic learning theory, but it does not need to directly build on what you have been studying. For the topics below, the papers/readings are suggestions --- and you don't have to read all the papers in a topic.

You are welcome to include the topic of your second presentation in your final paper, and there are some suggestions below of what to pair with various second presentations.

By 10/20, you must submit on Canvas a proposal for your final paper. You should include in your proposal:

- What you plan to read (this can include content from your 2nd presentation)
- What you aim to do in your paper. You should spend about a paragraph explaining how you will do this. Some suggestions for aims are:
    - **Tutorial.** Write a complicated proof more clearly, and contribute useful figures or examples.
    - **Survey.** Put together several papers to tell a story of how a field has progressed.
    - **Application.** Explain how mathematical ideas from our class, or from your paper, relate to modern applications.
- What the math content will be. At least 4 pages of your paper should include math proofs. This doesn't mean you have to prove the main theorem.

If you'd like to speak before then about ideas, reach out. For choosing a topic, you are welcome to use AI to help you more quickly understand what these topics are, or what alternative papers you could read.

Topics Related to Modern Advances in Machine Learning / AI

- Complexity Measures for Neural Networks
    - Covering numbers (UML chapter 27)
    - [1706.08498] Spectrally-normalized margin bounds for neural networks
    - [1712.06541] Size-Independent Sample Complexity of Neural Networks
- Challenges to traditional uniform-convergence-based understanding for Neural Networks
    - Rademacher Complexity (UML chapter 26)
    - [1611.03530] Understanding deep learning requires rethinking generalization (no proofs)
    - [1902.04742] Uniform convergence may be unable to explain generalization in deep learning
    - Learnability, Stability and Uniform Convergence
- Learning to play two-players games (eg. Poker)
    - An Introduction to Counterfactual Regret Minimization
    - [1705.02955] Safe and Nested Subgame Solving for Imperfect-Information Games
    - Recommended 2nd Presentation: Games + Minimax

New Questions & Definitions in Learning theory

- [2404.06757] Language Generation in the Limit (and follow-ups, eg [2605.10809] Mistake-Bounded Language Generation)
- [2107.08444] A Theory of PAC Learnability of Partial Concept Classes
- [2011.04483] A Theory of Universal Learning

Progress on Fundamental Learning Theory Questions

- Multiclass Learnability
  - UML chapter 29
  - [1405.2420] Optimal Learners for Multiclass Problems
  - [2203.01550] A Characterization of Multiclass Learnability (breakthrough, but challenging!)
  - [2303.17716] Multiclass Online Learning and Uniform Convergence
- Optimal PAC Learners
  - An Almost Optimal PAC Algorithm
  - [1507.00473] The Optimal Sample Complexity of PAC Learning [I'd recommend this one the most]
  - Majority of 3 [then this one second]
  - [2212.02264] Bagging is an Optimal PAC Learner
- Sample Compression Schemes
  - [2410.13012] Sample Compression Scheme Reductions
  - Recommended 2nd Presentation: Sample Compression 2

Active Learning

- Two faces of active learning / Dasgupta
- The True Sample Complexity of Active Learning*

Connections between Online Learning and Differentially Private Learning

- [1806.00949] Private PAC learning implies finite Littlestone dimension (This is already an option for presentation 2, so you can just add something small for presentation 3)
  - I have some blogpost notes here: https://differentialprivacy.org/alt-highlights/
- [2003.00563] An Equivalence Between Private Classification and Online Prediction (This is also a presentation 2 option, same applies)
  - This talk by one of the authors may be useful: https://www.youtube.com/watch?v=wk910Aj559A
- To add to either of these, you could talk about technical follow-ups, or about more general topics in Differential Privacy.
  - [2304.03996] A Unified Characterization of Private Learnability via Graph Theory (technical follow-up)
  - The Algorithmic Foundations of Differential Privacy Choose something from this textbook.