From Regression to Multiclass Learning: On the Fundamental Finite Character of Learnability in Supervised Learning with Infinite Labels

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ABSTRACT

Recent work on learning has yielded a striking result: the learnability of various problems can be undecidable, or independent of the standard ZFC axioms of set theory. Furthermore, the learnability of such problems can fail to be a property of finite character: informally, it cannot be detected by examining finite projections of the problem. On the other hand, learning theory abounds with notions of dimension that characterize learning and consider only finite restrictions of the problem, i.e., are properties of finite character. How can these results be reconciled? More precisely, which classes of learning problems are vulnerable to logical undecidability, and which are within the grasp of finite characterizations? We demonstrate that the difficulty of supervised learning with metric losses admits a tight finite characterization. In particular, we prove that the sample complexity of learning a hypothesis class can be detected by examining its finite projections. For realizable and agnostic learning with respect to a wide class of proper loss functions, we demonstrate an exact compactness result: a class is learnable with a given sample complexity precisely when the same is true of all its finite projections. For realizable learning with improper loss functions, we show that exact compactness of sample complexity can fail, and provide matching upper and lower bounds of a factor of 2 on the extent to which such sample complexities can differ. We conjecture that larger gaps are possible for the agnostic case. At the heart of our technical work is a compactness result concerning assignments of variables that maintain a class of functions below a target value, which generalizes Hall's classic matching theorem and may be of independent interest. Joint work with Julian Asilis, Siddartha Devic, Shaddin Dughmi, and Vatsal Sharan

BIOGRAPHY

Shang-Hua Teng is a University Professor and Seely G. Mudd Professor of Computer Science and Mathematics at USC. He is a fellow of SIAM, ACM, and Alfred P. Sloan Foundation, and has twice won the Gödel Prize, first in 2008, for developing smoothed analysis, and then in 2015, for designing the breakthrough scalable Laplacian solver. Citing him as, "one of the most original theoretical computer scientists in the world", the Simons Foundation named him a 2014 Simons Investigator to pursue long-term curiosity-driven fundamental research. He also received the 2009 Fulkerson Prize, 2023 Science & Technology Award for Overseas Chinese from the China Computer Federation, 2022 ACM SIGecom Test of Time Award (for settling the complexity of computing a Nash equilibrium), 2021 ACM STOC Test of Time Award (for smoothed analysis), 2020 Phi Kappa Phi Faculty Recognition Award (2020) for his book Scalable Algorithms for Data and Network Analysis, 2011 ACM STOC Best Paper Award (for improving maximum-flow minimum-cut algorithms). In addition, he and collaborators developed the first optimal well-shaped Delaunay mesh generation algorithms for arbitrary three-dimensional domains, settled the Rousseeuw-Hubert regression-depth conjecture in robust statistics, and resolved two long-standing complexity-theoretical questions regarding the Sprague-Grundy theorem in combinatorial game theory. For his industry work with Xerox, NASA, Intel, IBM, Akamai, and Microsoft, he received fifteen patents in areas including compiler optimization, Internet technology, and social networks. Dedicated to teaching his daughter to speak Chinese as the sole Chinese-speaking parent in an otherwise English-speaking family and environment, he has also become fascinated with children's bilingual learning.

All are welcome!

In case of questions, please contact Prof Minming Li at minming.li@cityu.edu.hk, or visit the CS Departmental Seminar Web at https://www.cs.cityu.edu.hk/events/cs-seminars/recent-cs-colloquiums.