THE UNIVERSITY OF CHICAGO | THE COMMITTEE ON COMPUTATIONAL AND APPLIED MATHEMATICS

Dissertation Defense

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Applied Topology and Geometry of Neural Codes and Data

TUESDAY, May 31, 2022, at 4:30 PM
Jones 303, 5747 S. Ellis Ave. Chicago, IL 60637

Zoom Info
https://uchicago.zoom.us/j/99307294520?pwd=bHhjRDVENUtJaUZndVdQL1EyYmtDZz09
Meeting ID: 993 0729 4520, Passcode: 426101
Full Zoom Info on following page

ABSTRACT

In the first half we discuss neural codes (joint work with Anne Shiu and Florian Frick), which seeks to answer the following question: Given an intersection pattern of arbitrary sets in Euclidean space, is there an arrangement of convex open sets in Euclidean space that exhibits the same intersections? This question is combinatorial and topological in nature, but is motivated by neuroscience. Specifically, we are interested in a type of neuron called a place cell, which fires precisely when an organism is in a certain region, usually convex, called a place field. The earlier question, therefore, can be rephrased as follows: Which neural codes, that is, patterns of neural activity, can arise from a collection of convex open sets? It was proved by Giusti and Itskov that convex neural codes have no "local obstructions," which are defined via the topology of a code's simplicial complex. Codes without local obstructions are called locally good, because the obstruction precludes the code from encoding the intersections of open sets that form a good cover. In other words, every good-cover code is locally good. We first show the converse: Every locally good code is a good-cover code, and furthermore that this extends to the closed-code case. We also prove that the good-cover decision problem is undecidable. Finally, we reveal a stronger type of local obstruction that prevents a code from being convex, and prove that the corresponding decision problem is NP-hard. In the second half we discuss persistent path homology (joint work with Brad Nelson). Persistent homology is a celebrated tool used to analyze filtrations of simplicial complexes that can arise considering point clouds in Euclidean space at different resolutions (such as forming the Cech complex). Path homology extends the theory of simplicial homology to the setting of path complexes, which can arise naturally from directed graphs. Persistent path homology combines both frameworks and allows us to analyze a digraph filtration (generating a barcode in the same way as in ordinary persistent homology). Using the Basic Applied Topology Subprograms package, we implement the reduction algorithm for computing persistent path homology that is faster than any existing implementation by orders of magnitude.

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