Carina Curto – Research Summary

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Building accurate representations of the world is one of the basic functions of the brain. It is well-known that when a stimulus is paired with pleasure or pain, an animal quickly learns the association. Animals also learn, however, the (neutral) relationships between stimuli of the same type. For example, a bar held at a 45-degree angle appears more similar to one held at 50 degrees than to a perfectly vertical one. Upon hearing a triple of distinct pure tones, one seems to fall "in between" the other two. An explored environment is perceived not as a collection of disjoint physical locations, but as a spatial map. In summary, we do not experience the world as a stream of unrelated stimuli; rather, our brains organize different types of stimuli into highly structured stimulus spaces. Regardless of immediate relevance to survival, it appears beneficial for the brain to reflect as much structure as possible of the outside world. *How does the brain do this?*

Broadly speaking, my research is devoted to answering this question, and to developing the mathematical tools necessary to do so. It integrates the study of *neural codes* with that of *neural networks*. While neural coding focuses on understanding the relationship between neural activity (as can be measured in neuroscience experiments) and external stimuli, neural network theory in neuroscience seeks to illuminate the relationship between the structure and dynamics of networks and the patterns of neural activity they generate.

In my research on neural coding, I am investigating error-correcting properties of neural codes as well as their ability to represent relationships between stimuli. As part of this work, I have developed a new algebro-geometric tool, the *neural ring*, to help uncover the relationship between the intrinsic structure of neural codes and that of the stimulus spaces they represent. I am particularly interested in geometric and topological stimulus space features, and in developing methods for extracting these features from neural codes using algebraic geometry, topology, and combinatorics.

My research on neural networks is two-pronged. On the one hand, I am interested in the *network encoding problem*, or how to design networks that encode a desired list of memory patterns while minimizing unwanted "spurious" states. On the other hand, quite a bit of my work is devoted to studying *bump attractor networks*, a type of neural network that has been particularly successful in modeling cortical and hippocampal areas. My recently awarded NSF grant proposes to integrate these two types of network studies. This line of research makes use of a wide range of mathematics, including dynamical systems, linear algebra, discrete geometry, and algebraic topology.

<u>Selected Publications</u>

C. Curto, A. Degeratu, V. Itskov. Flexible memory networks. *Bulletin of Mathematical Biology*, Vol 74(3):590-614, 2012.

V. Itskov*, C. Curto*, E. Pastalkova, G. Buzsaki. Cell assembly sequences arising from spike threshold adaptation keep track of time in the hippocampus. *Journal of Neuroscience*, Vol. 31(8):2828-2834, 2011. (* equal contribution)

C. Curto, S. Sakata, S. Marguet, V. Itskov, K.D. Harris. A simple model of cortical dynamics explains variability and state-dependence of sensory responses in urethane-anesthetized auditory cortex. *Journal of Neuroscience*, Vol. 29(34):10600-10612, 2009.

C. Curto*, V. Itskov*. Cell groups reveal structure of stimulus space. *PLoS Computational Biology*, Vol. 4(10): e1000205, 2008. (* equal contribution)