Inverse problems in cognitive science.
SSL 206, TT 9:30-10:50
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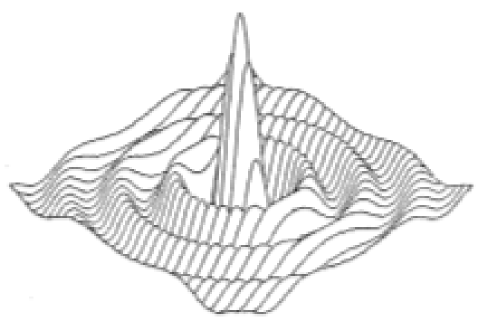
Inferences are ubiquitous in cognition: forming mental representations of objects and categories, forming representations of other people's mental representations (aka Theory of Mind), identifying causes based on available outcomes (e.g., medical diagnosis), forming 3D percepts from 2D retinal images, formulating scientific theories based on experimental data, learning and reasoning, and linguistic communication. While it is easy to see that these individual cognitive functions require different types of experimental methodologies (compare experiments on 3D vision to experiments on linguistic communication), there is one underlying theoretical formalism, called the Theory of Inverse Problems. Inverse Problems are almost always computationally difficult because the data at hand are consistent with more than one possible interpretation. The question of how to choose a unique, and ideally the correct interpretation has been studied for over 50 years, across all branches of science. A universal approach in regularization and Bayesian methods of solving inverse problems is to impose *a priori* constraints (aka priors) on the family of possible interpretations. Effective constraints usually come from the analysis of the problem at hand, rather than from the collected data.

Look at the figure below (from K.A. Stevens, 1979). You see a 3D surface. The percept is very compelling, and you might have an impression that there is only one way to interpret this image. Obviously, a 2D line drawing on a 2D (flat) surface of your screen is another interpretation. Next, turn the figure upside-down. Your 3D interpretation is now "paradoxical" (to use Stevens's description). Clearly, there is more to 3D percept than the 2D sensory data producing it. The same is true in all cognitive inferences.



This class will review examples of inverse problems across several areas of cognitive science and provide a description of the methods for solving them. The relation between deterministic and probabilistic formulations will be discussed, as well. Grades will be based on projects and presentations.

Topics:

Week 1: Introduction.
Week 2: Multidimensional Scaling as an inverse problem.
Week 3: What happens when there is no data in a subspace of your problem? The role of symmetry.
Week 4: Causal inference.
Week 5: Model selection.
Week 6: Theory of Mind.
Week 7: Bayesian models of perception.
Week 8: Bayesian models of cognition.
Week 9: 3D vision based on symmetry.
Week 10: Class presentations.