

Six Problems in Search of a Graduate Student

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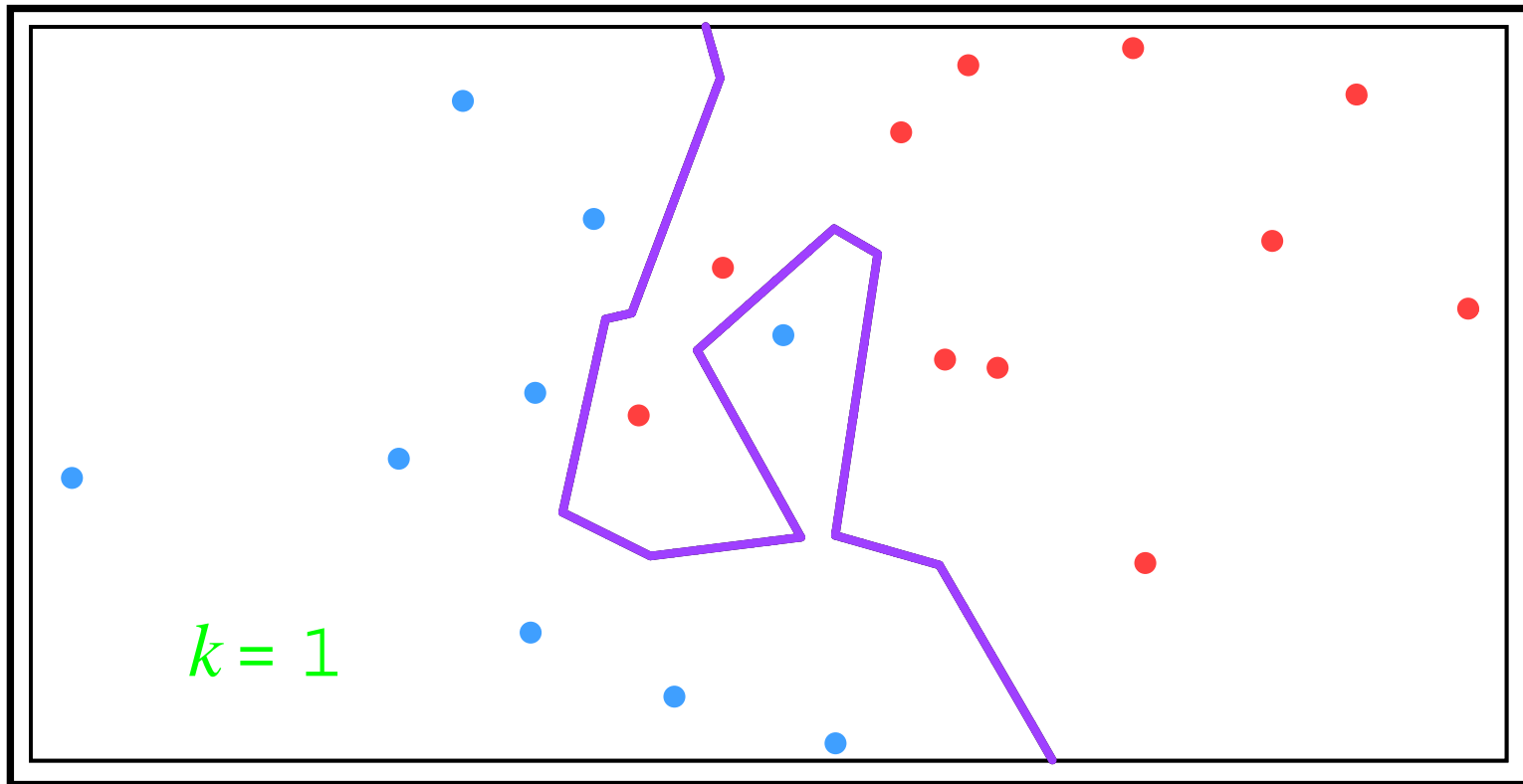
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1. Derivation of nonuniform metrics for k -nearest neighbor classifiers.
2. Learning nonuniform metrics from sample data.
3. Verification and validation of feedforward neural networks.
4. Hierarchical regression models.
5. Pattern matching tools for VLSI design.
6. Reinforcement learning for puzzles and games.

k -nearest neighbor classifiers



Derivation of Nonuniform metrics

Let $\mathbf{x}_1, \mathbf{x}_2 \in \mathbb{R}^d$, and $A \in \mathbb{R}^{d \times d}$. Consider the *uniform* metric

$$\mu(\mathbf{x}_1, \mathbf{x}_2) = \|A(\mathbf{x}_1 - \mathbf{x}_2)\|_p,$$

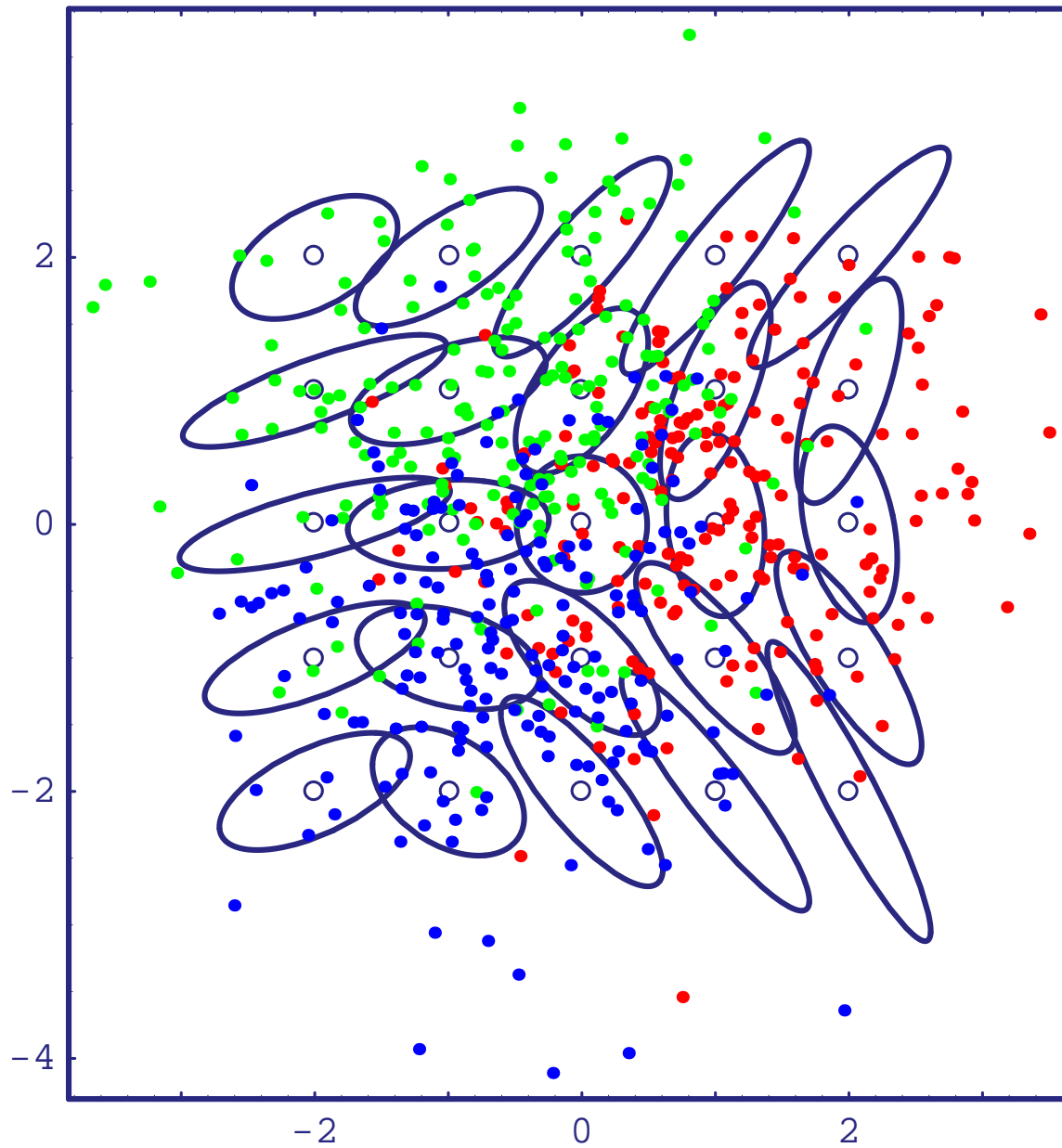
Theorem 1 *Under certain weak assumptions, there exist coefficients c_2, \dots, c_m , such that the finite-sample risk (i.e., the probability of error) of a k -nearest neighbor classifier that uses a reference sample of n patterns, can be expressed as,*

$$R_n(k) = R_\infty(k) + \sum_{j=2}^m c_j n^{-j/d} + O\left(n^{-(m+1)/d}\right).$$

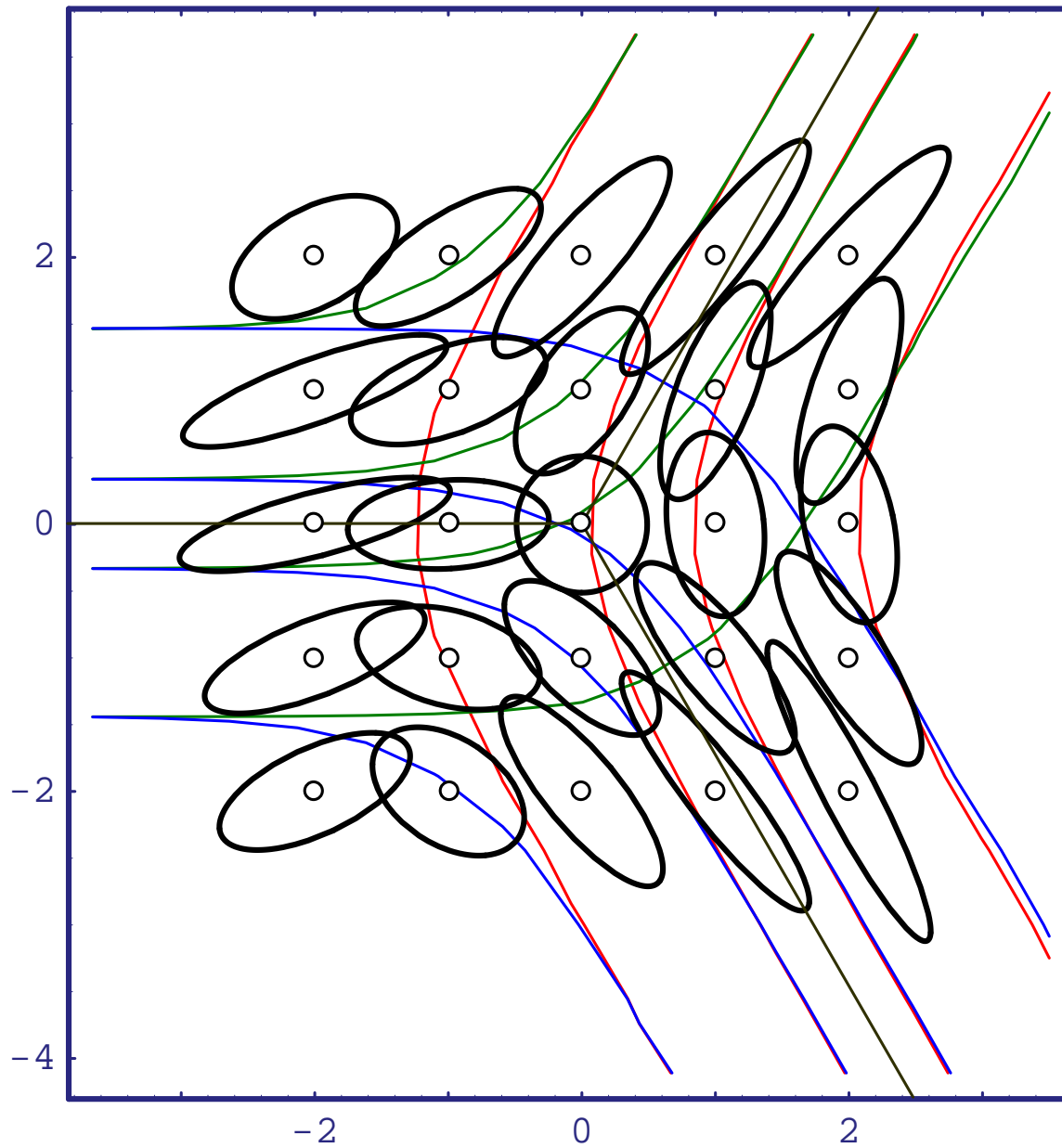
Minimization of c_2 with respect to p and A yields an optimal uniform metric. (Snapp and Venkatesh, *Annals of Statistics*, 26, 1998, pp. 850-878.)

Problem 1: Can one analytically derive problem-dependent, optimal, local metrics?

Nonuniform metrics: Local Polynomial Models



Nonuniform metrics: Local Polynomial Models (cont.)



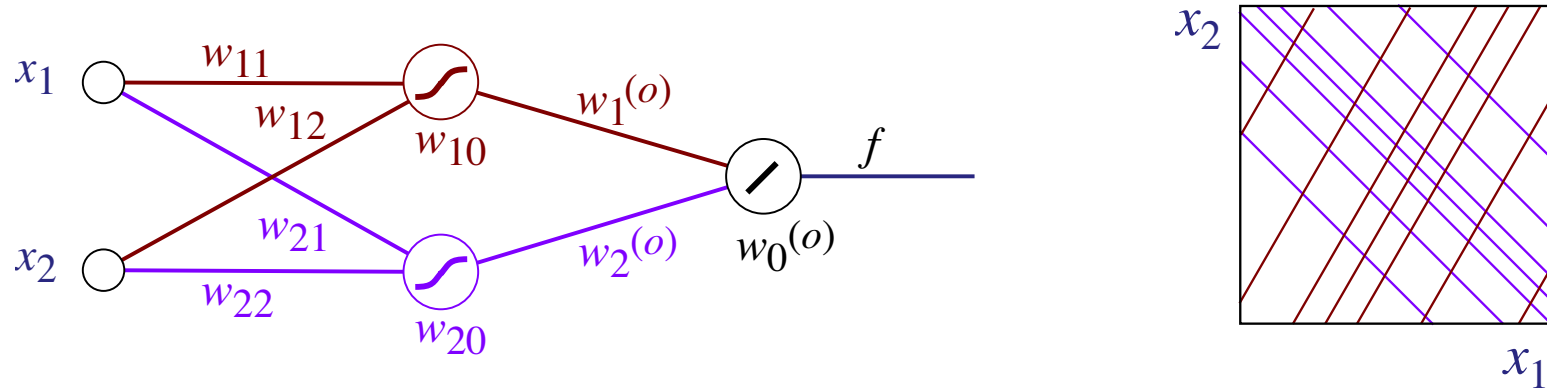
Nonuniform metrics

Other approaches,

- Genetic Programming (with Peter Duval)
- Information Geometry

Problem 2: Can one construct an algorithm that learns approximately optimal local metrics from sample data?

Verification and Validation of Neural Networks

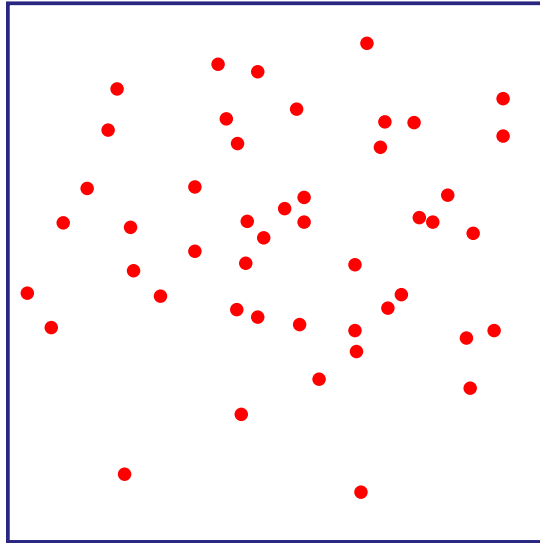


Consider n input units, m hidden units, and k isosurfaces per unit, then the

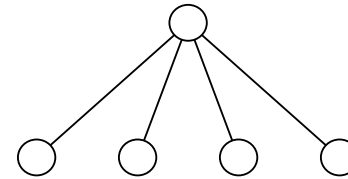
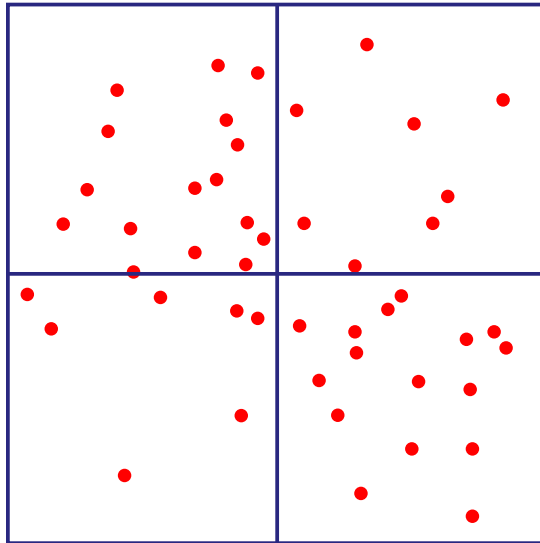
$$\text{Number of parallelepipeds} = \sum_{i=0}^n \binom{m}{i} k^i \leq (1+k)^m.$$

Problem 3: Can one certify that a trained neural network will perform satisfactorily in a safety-critical application?

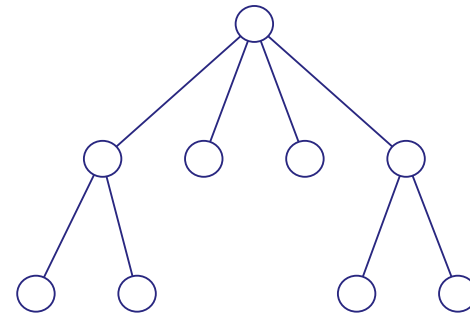
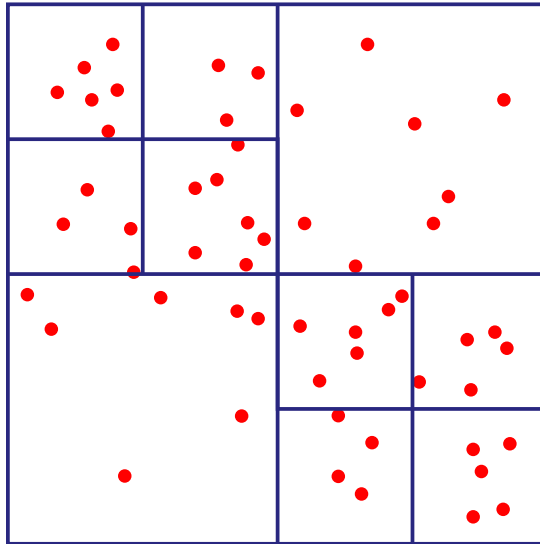
Hierarchical Regression Models



Hierarchical Regression Models



Hierarchical Regression Models



Problem 4: How does hierarchical regression compare against alternative on-line estimation models, (e.g., nearest-neighbor regression, more general local polynomial models)?

Pattern matching tools for VLSI design

Project with Dan Nardi, Jo Ellis-Monaghan (SMC), and John Cohn (IBM).

Dan Nardi's Master's defense will occur on October 16th at 11:00am in 322 Votey.

Problem 5: Can this algorithm be generalized to other geometries. What are some other practical applications?

Reinforcement Learning for Puzzles and Games

- Poker
- Peg Solitaire
- Rubik's Cube
- Hex
- Go

Problem 6: Discover new applications for reinforcement learning algorithms.