Instance Based Learning

Some material on these is slides borrowed from Andrew Moore's machine learning tutorials located at:

http://www.cs.cmu.edu/~awm/tutorials/

Problems with Neural Networks

- Networks learn by tweaking parameters to fit the data.
- Then the data is thrown away.
- Problems:
  - Training to fit new data may erase what we learned before.
  - We need to have the right set of parameters.

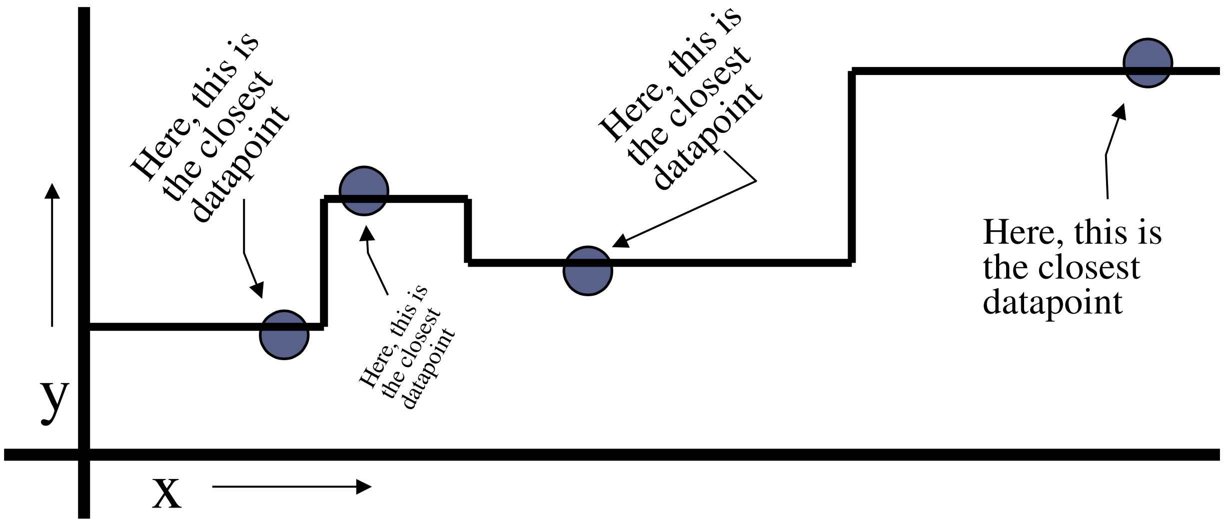
Instance Based Learning

- Keep all of the training data around.
  - Refer back to it when we need to make a prediction
- Simplest example: 1-Nearest Neighbor.
- Given input-output pairs: $(\boldsymbol{x}_{1}, y_1), (\boldsymbol{x}_{2}, y_2), \ldots, (\boldsymbol{x}_N, y_N)$ that come from some unknown function $y = f(\boldsymbol{x})$.
- Given a query, find the nearest input point:

$$c = \underset{i}{argmin}(\|\boldsymbol{x}_i - \boldsymbol{x}_q\|)$$

- Then predict $\hat{y} = y_c$

1-Dimensional Example...



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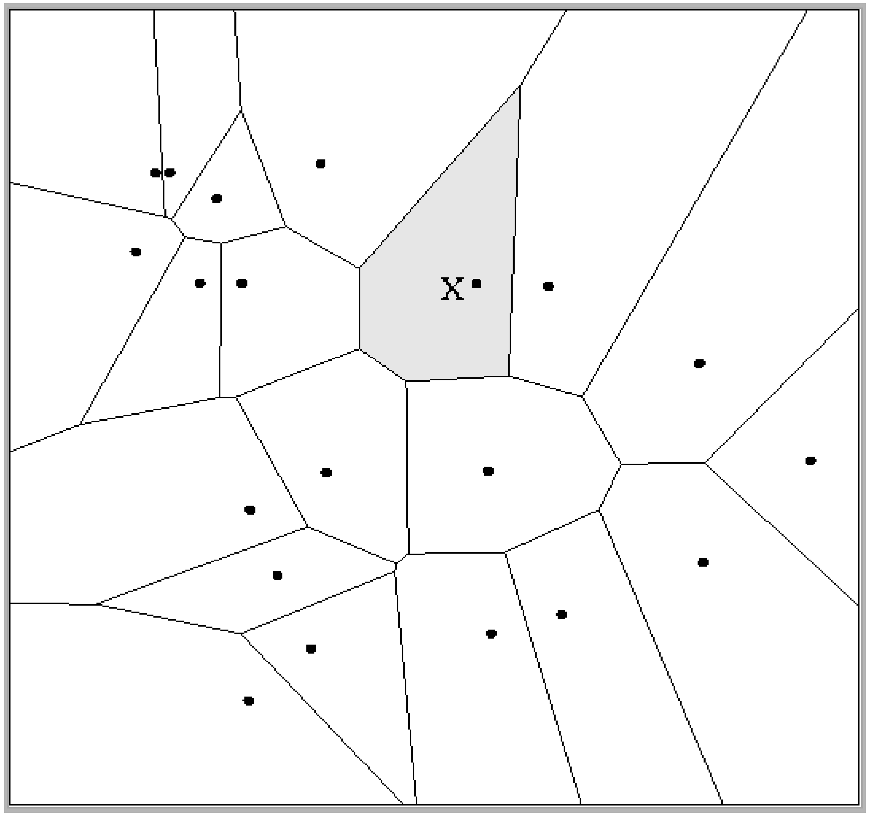
2-Dimensional Example



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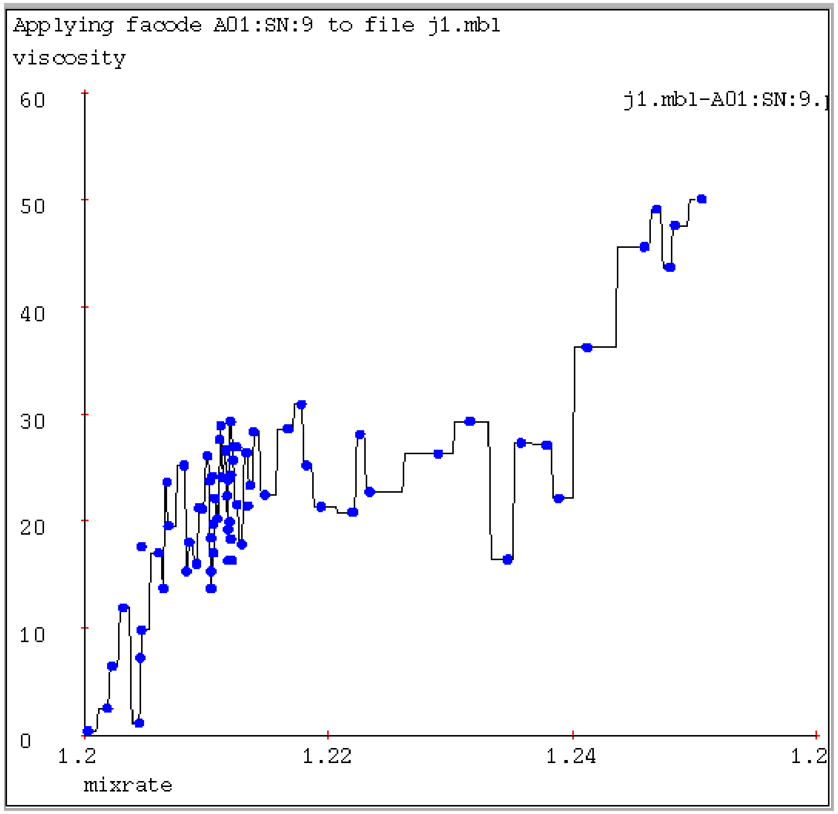
Problems With 1-NN

- No interpolation.
- Susceptible to noise.



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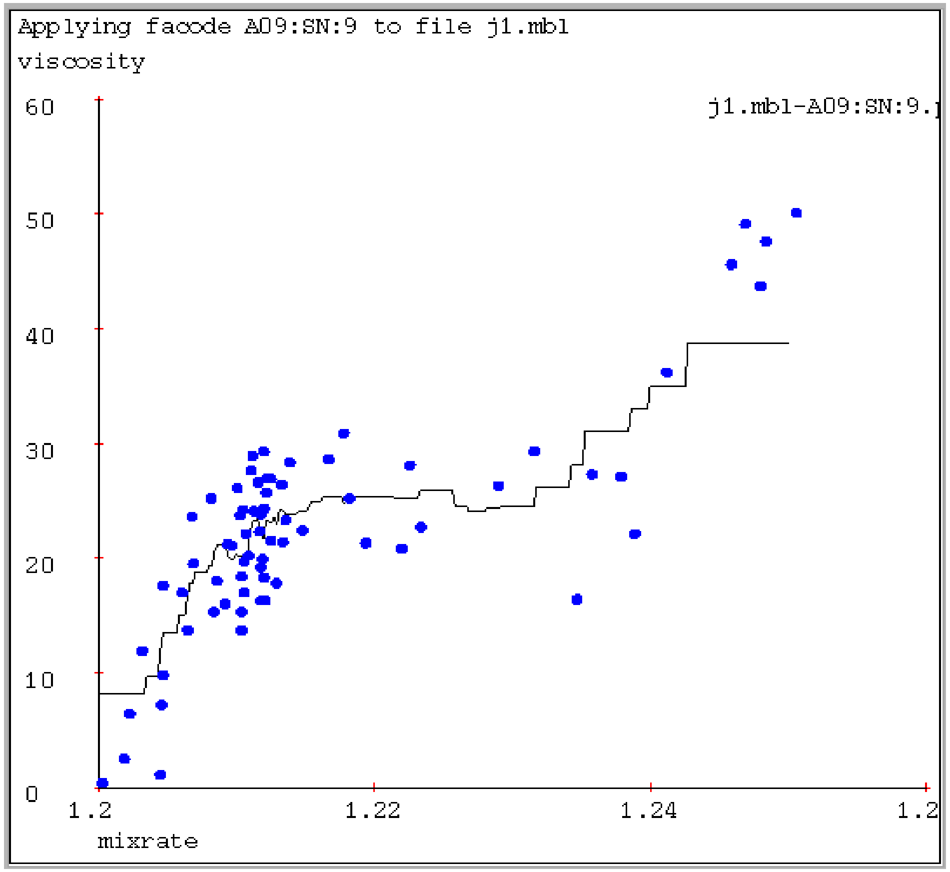
Solution (?) K-NN

- Average the output values of the k nearest neighbors – Better.
- Odd behavior at the edges.
- The fit is jerky.
- (We can find neighbors efficiently using kd-trees)

9-NN



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Solution (?) Kernel Regression

- Use all of the training points for every query.
- Take a weighted average, where the weight is based on a kernel function K:

$$\hat{f}(\boldsymbol{x}_q) = \frac{\sum_i K(\boldsymbol{x}_i, \boldsymbol{x}_q) y_i}{\sum_i K(\boldsymbol{x}_i, \boldsymbol{x}_q)}$$

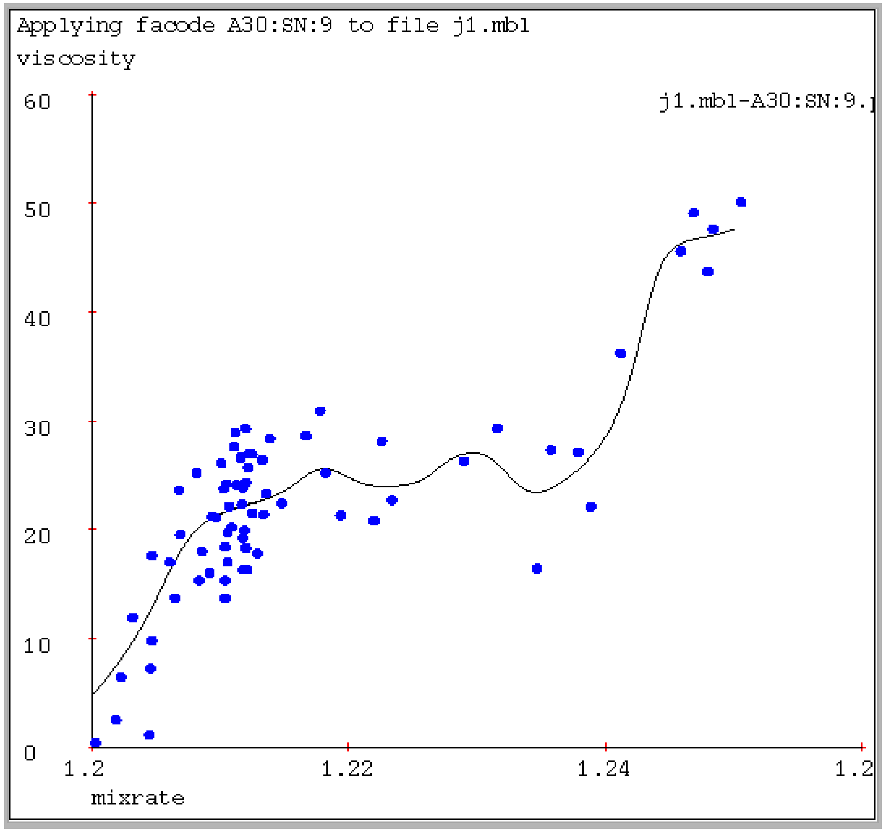
- Popular choice is a Gaussian kernel:

$$K(\boldsymbol{x}_q, \boldsymbol{x}_i) = \exp\left(-\frac{\|\boldsymbol{x}_q - \boldsymbol{x}_i\|^2}{2w^2}\right)$$

- Here w controls width.

Kernel Regression Example

- Looks better.
- Still a little bumpy.



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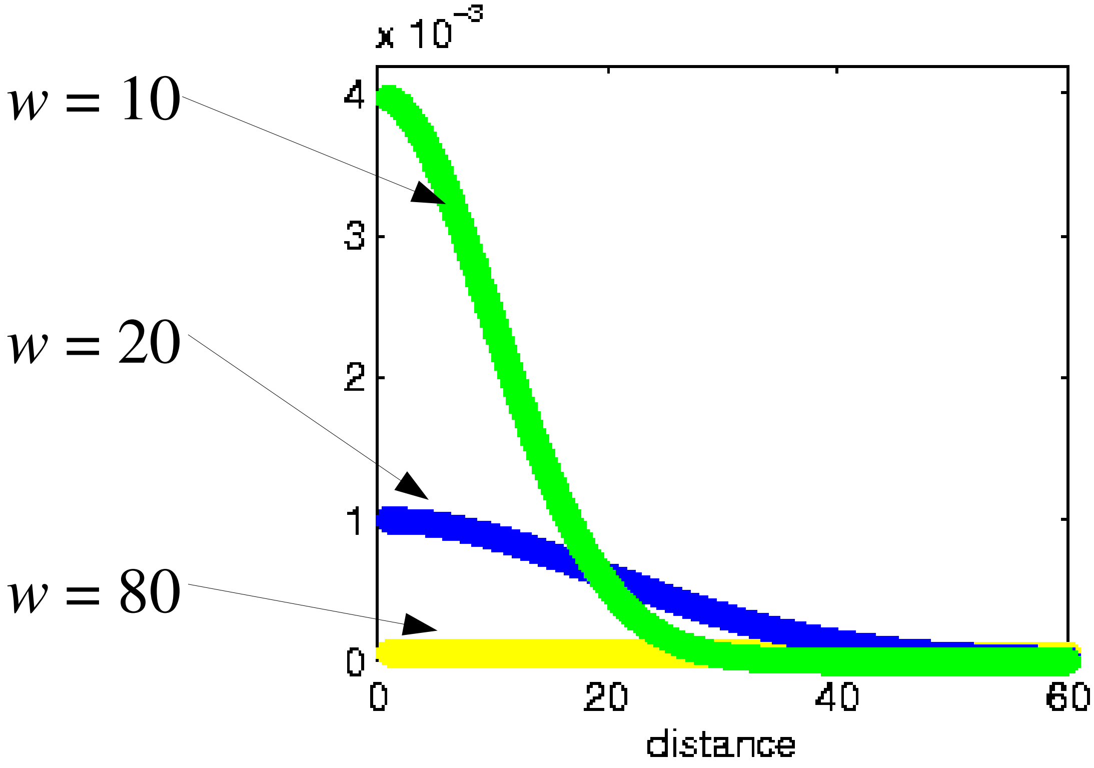
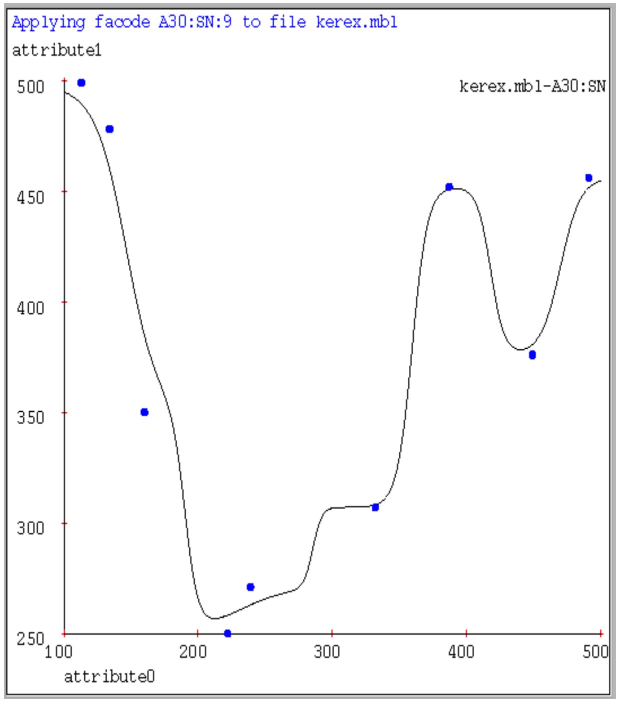
Effect of *w* on the Kernel Function

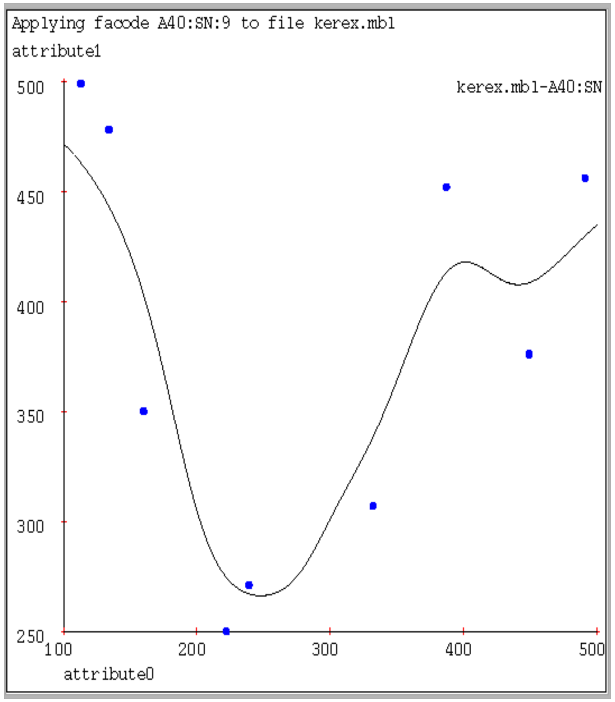


Effect of Changing w on Regression

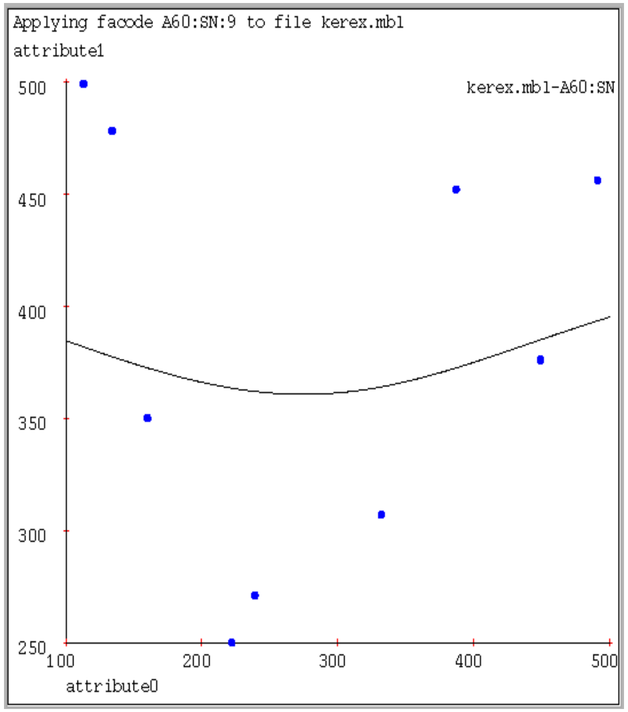
$w = 10$



$w = 20$



$w = 80$



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Instance Based Classification

- Very easy to extend these techniques to classification.
- K-NN classification:
  - Find the K-NN to the query point.
  - Return the class that has the most votes.
  - Break ties randomly.
- Kernel classification
  - Exactly the same thing, except weight votes by the kernel function.
- Multi-class classification is just as easy as two class.

Difficulties

- Distance metric/Kernel – need to be careful if different dimensions are scaled differently.