Where are we?

- **Bayesian classification**
- **Statistical modeling**
  - *Gaussian modeling*
  - *Mixture-of-Gaussian modeling (EM)*
- **Examples**
  - *Synthetic examples*
  - *Sky/ground classification*
  - *Two objects*
  - *Two textures*
- **Up next: another way of doing statistical modeling...**

Histogram-based modeling

Basic idea:

- Quantize feature space
- Count frequencies of occurence for each region
- Normalize

Ways of quantizing:

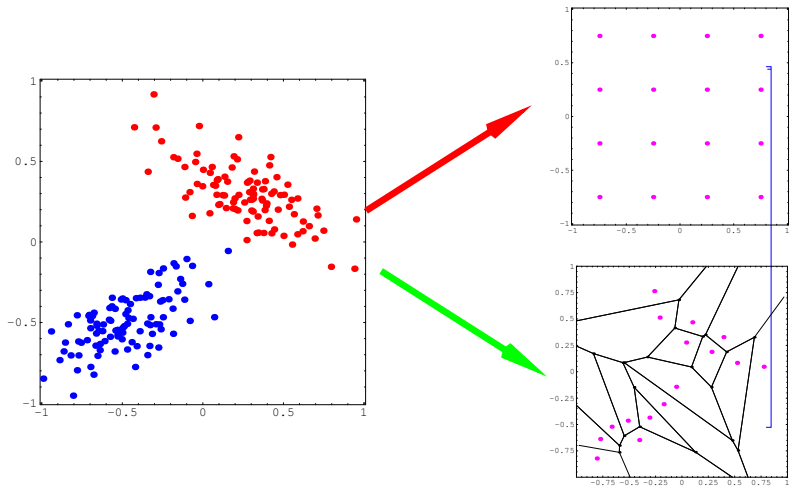
- Uniform quantization
- *Vector quantization*

Pro: arbitrary distributions...

Examples... (*Mathematica*)

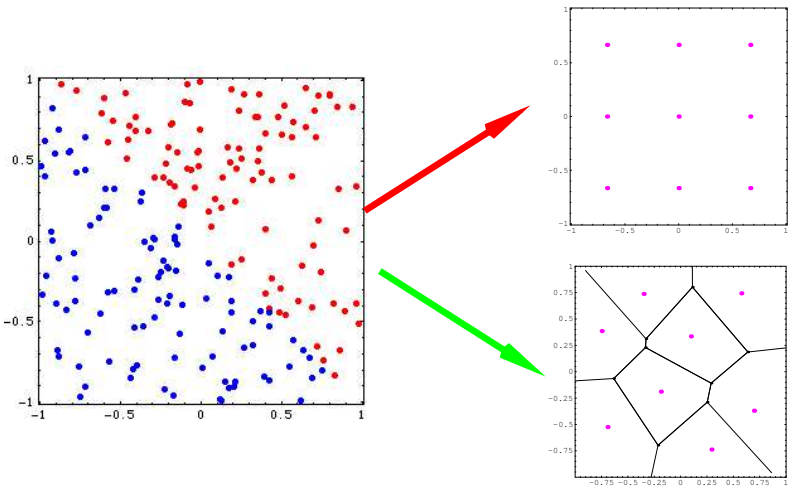
Vector quantizaton

Uniform vs. vector quantization



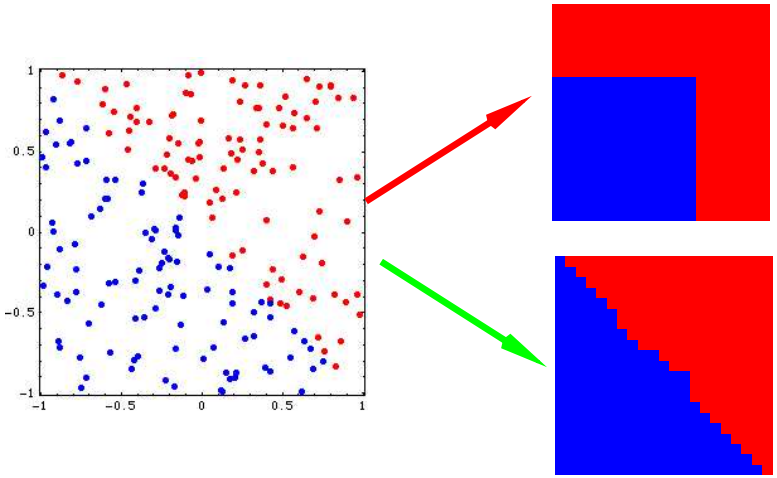
Histogram classification

Uniform vs. vector quantization



Histogram classification

Uniform vs. vector quantization



Vector quantization algorithm

1. **Initialization:** Choose some initial setting for the L centroids $\{\mu_i\}$ in the VQ codebook.

2. **Classification:** Classify each $\mathbf{x}_j$ into class ω_i such that,

$$dist(\mathbf{x}_j, \mu_i) \le dist(\mathbf{x}_j, \mu_l)\ ,\ \forall l\ .$$

3. **Codebook update:** Update the centroid for each class ω_i,

$$\mu_i = \frac{1}{n_i}\left(\sum_{\mathbf{x}_j \in \omega_i} \mathbf{x}_j\right)$$

4. **Termination:** Stop when the distortion D has decreased below some threshold level, or when the algorithm has converged to a constant level of distortion.

Distortion D

$$D = \sum_{j=1}^{n} \min_i dist(\mathbf{x}_j, \mu_i)$$

VQ: a limiting case of EM

Update only μ_i and let:

$$P(\omega_i) = 1/k = \text{constant}$$

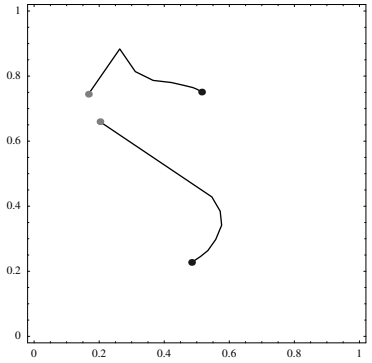
$$\Sigma_i = \sigma^2 I \text{ where } \sigma^2 \to 0$$

So:

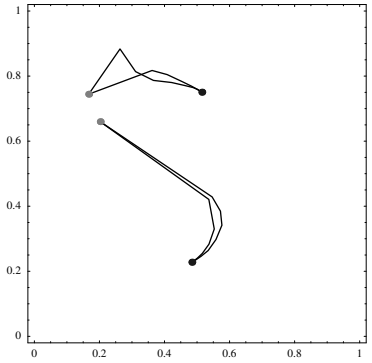
$$\lim_{\sigma^2 \to 0} \mu_i = \lim_{\sigma^2 \to 0} \left[\frac{\sum_{j=1}^{n} P(\omega_i|\mathbf{x}_j)\mathbf{x}_j}{\sum_{j=1}^{n} P(\omega_i|\mathbf{x}_j)} \right] = \frac{1}{n_i}\left(\sum_{\mathbf{x}_j \in \omega_i} \mathbf{x}_j\right)$$

Convergence comparison

Uniformly distributed data



VQ convergence



EM convergence ($\sigma = 0.1, 0.001$)

LBG VQ algorithm

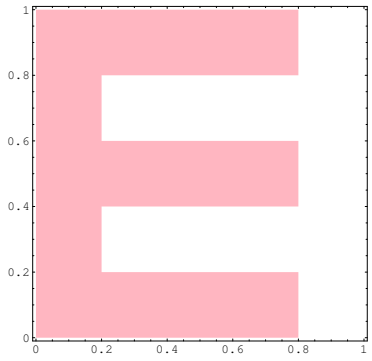
1. **Initialization: one centroid of all data**

2. **Splitting: split each centroid into two ($\mu_i + \varepsilon, \mu_i - \varepsilon$).**
3. **Vector quantization on current number of centroids.**

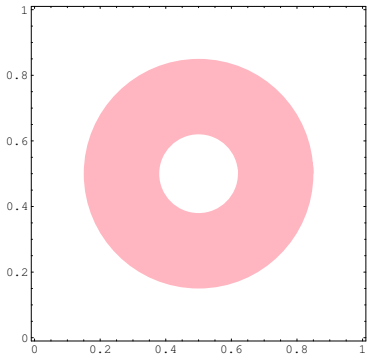
4. **Iterate steps 2 and 3 until satisfied...**

Examples (synthetic data)

Uniformly distributed data



Example #2



Example #1

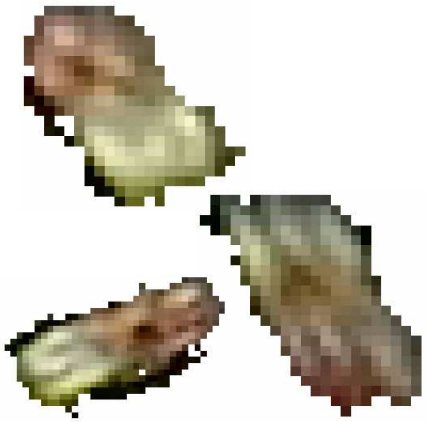
Let's see some action...(animations)

Example (real data)

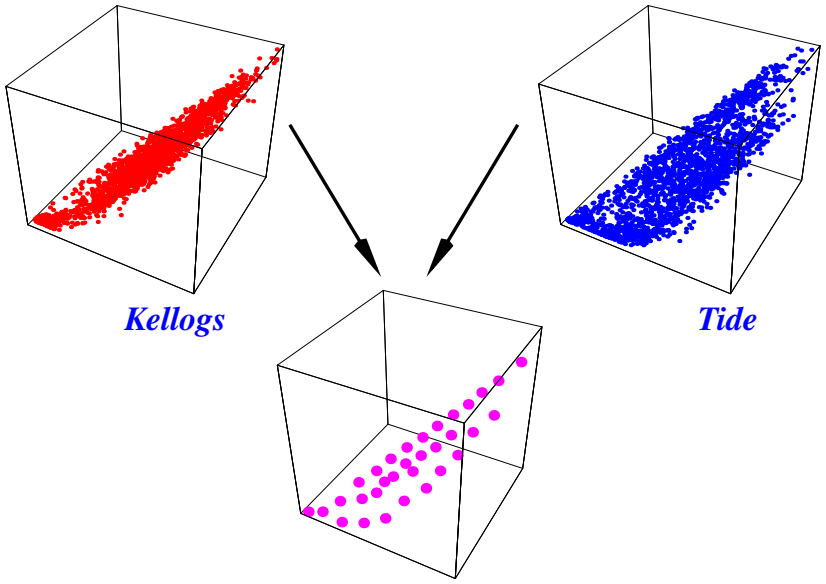
Object detection (qt movie/race)

Tide car examples

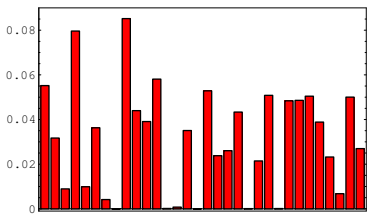
Kellogs car examples



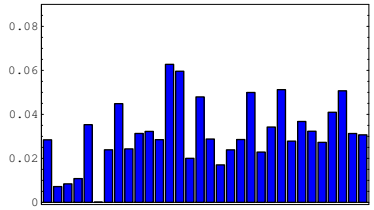
Vector quantization



Histograms



Kellogs



Tide

avg. P(data|histogram)