1) Mode Finding with a Density Space
   [statistics]
2) Satellite Image Classification
   [image retrieval]

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Goal: to Locate Clusters in Point Patterns

- Clustering algorithms require to specify $K$ or $h$ (bandwidth)
- Mean-shift (no $K$):
  - but requires $h$
  - follows a \textit{gradient}

- \textbf{solution}:
  1) vary $h$ (bandwidth)
  2) estimate density to be indep. of gradients
  \rightarrow operate in density space
  (not new, but not properly worked out)
Generating a Density Space
[1D example]

- Parzen window at each point [the usual statistics]
- ...for different $h$ (win sizes)
  → bandwidth axis
Mode Finding with 3 Steps

1. Detect max & bumps for each $h \rightarrow$ clots
2. Correlate clots across $h$ \rightarrow consistency
3. Select most consistent \rightarrow modes of distribution

\rightarrow requires a strategy/focus
e.g. global-to-local
Bimodal: 2 sources separating increasingly

- 2 Dimensions
- 1 Dimension (overestim.)
- 4 Dimensions
- 6 Dimensions (underestim.)

(general phenomenon with density estimation)
3 sources increasingly separated

# detected modes

separation

<
4 sources increasingly separated

# detected modes
1 source within another (a cluster within noise)

# detected modes

increasing density

<
2 sources embedded, separating

# detected modes
Further Confirming 2D Visually

spotted modes

→ looks very promising: not applied as grouping method yet, but use 1D density estimation
Summary Density Space

• Allows a truly non-parametric mode spotting (and probably more)
• Requires the choice of a selection strategy (focus), e.g. global-to-local
• Complex: \( O(N^2)K \)  (\( K = \# \) of bandwidths)
• Works up to dimensionality ca. 5
• use the 1D density estimation already
(Satellite) Image Classification

• My preprocessing: based on contour analysis
  - Canny edge detection, edge linking
  - Curve partitioning [Rasche 2010 in Int Jrnl CV]
  - Grouping segments [Rasche, submitted]
    (density estimation used...)

• Evaluation on [Yang & Newsam 2010]: 21 Classes: agriculture, airports, intersections,... benchmark at 81% with SIFT features (histograms of image gradients): equalized and rising.
Airport

Airplanes well described by hyperbolas \((2\text{ curved segments vis-à-vis, facing away from each other})\)
Buildings

Ribbon feature is dominant \( \parallel \) (two straight segments, parallel, vis-à-vis)
Summary Classification

• Descriptor generation: relatively complex – as opposed to SIFT -, but still taking only a few seconds in Matlab (per image)

• ( Other benchmarks reached: MPG7, Urban&Landscape, Caltech101 )

• Representation much smaller, rel. fast matching

• For image understanding: no further preprocessing required

• Could be optimized with density estimation
Slide of Interest

• Seeking applications, e.g. taxonomy
• Object identification?
• Segmentation with density estimation?
• ...anything where structure needs to be interpreted
Density Estimation

- **Parametric:** Expectation-Maxim. (EM), Max-Likelihood (MLE)
- **Semi-Parametric:** Clustering (k-Means)
- **Non-Parametric:** Kernel Density Est. (Parzen)

→ requires selection of appropriate bandwidth \( (h) \)...

...is still a parameter
Locally Adaptive Density Estimation

[Variable Bandwidth]

1) Adjustment of $h$ to local data neighborhood
   - balloon estimator [Loftsgaarden & Quesenberry 65]
   - sample-point estimator [Breiman, Meisel & Purcell 77]
   ...does not work well for multi-modal distributions.

2) Varying of $h$ systematically $\rightarrow$ space
   [Minnotte & Scott 93], [Chaudhuri & Marron, 99]
   ...no obvious improvement.