HW 4: Advanced Topics in Computer Vision (580.464)

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Due 05/02/05

1. **(5+0+8+8+5=26 points) Evaluation of Central Clustering Algorithms**
   (a) Write a function `means = polysegment(x,n)`, with `means` $\in \mathbb{R}^{2\times n}$ and `x` $\in \mathbb{R}^{2\times N}$, that implements the algebraic algorithm for clustering 1-D or 2-D data distributed around n cluster centers.
   (b) Investigate the function `kmeans` in MATLAB, that implements the Kmeans algorithm for clustering data distributed around n cluster centers.
   (c) Write a function `[means, sigma] = EM(x,n)`, with `means` $\in \mathbb{R}^{D\times n}$ and `x` $\in \mathbb{R}^{D\times N}$ that implements the EM algorithm for clustering data drawn from a mixture of n Gaussians with mean μ_j and covariances $\sigma_j^2 I$, for $j = 1, \ldots, n$.
   (d) Write a script that generates data in $\mathbb{R}^2$ distributed according to a mixture of two Gaussians with means $(-2,-2)$ and $(2,2)$, and common standard deviation σ. Assume that the mixing proportions are $\pi_1 = \pi_2 = 1/2$. Plot the mean number of iterations and the mean error in the estimation of the means as a function of σ for $\sigma = 0.1{:}0.1{:}1$ for 1,000 realizations of 200 points for the following algorithms: Polysegment, Kmeans randomly initialized, EM randomly initialized, EM initialized with Kmeans. If possible, use the convergence criterion in the function `kmeans` to determine convergence for EM.
   (e) Run Kmeans with multiple random initializations and choose the one giving the minimum error. Plot a figure with 10 curves of error as a function of sigma for a number of restarts of 1:1:10.

2. **(14 points) Intensity-based Image Segmentation.** Use `polysegment`, `kmeans` and `EM` to segment the penguin, baseball and spinal cord images on the course webpage. Use $0 : 1/(n-1) : 1$ as the n initial cluster centers for `kmeans` and `EM`.

3. **(20 points) Texture-based Image Segmentation**. Use `GPCA`, `kmeans` and `EM` to segment the tiger and other images on the course webpage. In each case, use the RGB values in a neighborhood Ω of size w around each pixel as a feature vector in $\mathbb{R}^w$. You may one to use τ principal components of your feature vectors to reduce computational complexity. What is the effect of w and τ in the segmentation? Report the values you use, and plot segmentation results.

4. **(20 points) Motion-based Image Segmentation**. Use `GPCA` to segment the point correspondences of the following video sequences in the course webpage: Kanatani1, Kanatani2, Kanatani3, three-cars, can-book. In each case, assume the number of groups is known, plot the grouping of the ordered data given by GPCA, and report the percentage of misclassified points. Try the algorithm applied to both normalized and un-normalized point correspondences. Which one works better? What is the effect of normalization on the segmentation results? Can you devise a strategy for normalization?

5. **(10+10=20 points) Modeling and Segmentation of Dynamic textures.**
   (a) Learn a dynamical model for the sequence of water in the class webpage using different orders for the dynamical model. Synthesize a new video sequence using the learnt model for different initial conditions. Generate a video with the original sequence and the synthesized sequence for the order and initial condition giving the best results.
   (b) Apply GPCA to the sequence in the course webpage to segment the two dynamic textures. Use different values for the number of principal components and choose the one giving the best results.