Project #1: Color Segmentation/Object Classification

ESE 650: Learning in Robotics

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Date: 1/24/2012

Outline of the Algorithm:

Mask Generation:

Initially the training images were ordered and a black and white image mask pertaining to the location of the red barrel was constructed using hand labeling of the training images using the MATLAB roipoly function. This image mask was stored for future use for testing and computing various color statistics.

Preprocessing:

The input image is then preprocessed to make it lighting invariant. First the image is converted to HSV color space and the brightness is adjusted using the imadjust function. The brightness adjustment is made dynamic to each image by first computing the mean brightness i.e. the mean of the V layer (in HSV) and using that in imadjust.

Since the color of interest is red additional preprocessing is done on the red layer. The HSV image is converted back to RGB and adaptive histogram equalization is done on the R channel.

Initial Statistics Evaluation:

The mask is then applied on the preprocessed image is then used to compute the various cluster means and their variances for initialization in the K-means and EM algorithm.

Color Segmentation:

Then various clustering algorithms were tested for the color segmentation.

1. Unsupervised K-means
2. K-means with pre-initialization and radius bounds for clusters
3. K-means with pre-initialization and bounds
4. Gaussian Mixture Model with fixed covariance matrix

Effective Method: K-means with the cluster means pre-initialized and means limited by color statistics was found to be most effective.

The output of the color segmentation stage was to give a black and white image with white patches for red and black for the rest.

Shape based filtering:

The black and white image is the preprocessed before shape estimation to fill holes and remove false positives which are scattered and small in area.

Regionprops command was then used to compute area, centroid, bounding box, major-axis orientation.

The following shape filtering methods were tested.

1. Area to square of perimeter ratio
2. Filled area to Bounding Box area
3. Aspect ratio of the Bounding Box (Height to width ratio)

Effective Method: A combination of filled area to bounding box area and Aspect ratio was found to be more effective.

If the barrel is tilted and at different orientations then the bounding box can be tilted based on the major axis orientation of the blob using the orientation stats from regionprops.

Results and Analysis:

Training Time Consideration:

The image was scaled down to 300x400 pixels to make the computation faster. The K-means convergence was estimated using the percentage of pixels changing cluster in 1 iteration.

Parameters	Stats
Unsupervised K-means convergence	17-25 iterations (for within 500 pixels change)
K-means with bound limited means	7-15 iterations (for within 500 pixels change)
Training time of overall algorithm	0.9 to 4 seconds per image
Optimal number of Clusters K	5

K-means with bounded means:

The K-means algorithm was modified by first pre-initializing the means based on the statistics from hand labeling. Since color of the barrel in RGB color space varied hugely even after preprocessing for Intensity changes, 3 nearby clusters were initialized Normal red, Bright Red and Brown and their means were bounded so that the clusters do not merge together.

Also in the Shape based filtering stage if the Normal Red cluster did not contain any good shapes near to barrel then the Bright red layer was processed to check for the existence of barrel.

Methods that did not work so well:

- GMM model did not give better results than K-means. This might be because of the fixed covariance matrix. Updating the covariance matrix each time would increase the complexity of the model. Also the GMM is slower than K-means.
- Use of LAB color space: The usage of only AB components of the LAB color space to make it lighting invariant did not work as there were different shades of red for the barrel and the Intensity layer was necessary for classification.
- Decorrstretch function in MATLAB distorted the colors a lot and hence was not useful
- Simple Histogram Equalization did not work as a single image itself had varied lighting conditions and hence Adaptive Histogram Equalization was needed.

Estimation of K by cross-validation:

The number of clusters K was estimated by cross validation

Optimal K was found to be 5