Gaussian Mixture Model Based Color Segmentation

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Abstract

Object detection is a significant part for robots to accomplish various tasks such as obstacle avoidance, localization and mapping and path planning. Color segmentation is one widely-used technique to identify and detect objects. In this paper, one Guassian mixture model based machine learning algorithm was developed to segment colors and detect a specific red barrel.

1. Introduction

This project was accomplished for coursework in ESE 650: Learning in Robotics at University of Pennsylvania. Object detection is an essential skill for robots to complete different kinds of tasks such as grasping or path planning, localization and mapping and even odometry. Color segmentation is one of good techniques to identify and detect objects. In this project one machine learning algorithm based on Guassian mixture model was developed to segment colors and detect a red barrel. After training an adaptive model, the algorithm should be able to determine both the center of detected barrel and the distance from the camera to the barrel.

2. Preprocessing of data

At an input, the training images were taken by a robot camera at different locations with varying brightness. The image name also contain the distance from the camera. So as to differentiate various lighting conditions, the RGB images were first converted to the Lab color space. The region of interest selected in each RGB image was chosen by MATLAB built-in function `roi2poly` and then converted into mask images. In the new Lab color space, images were then stored as an N $\times$ 3 matrix where N is the number of pixels and 3 is the three dimensions in Lab space.

3. Segmentation Algorithm

The masks generated in the preprocessing data stage were then used to compute the various cluster means and their variances for initialization in the K-means and EM algorithm. First, the Gaussian mixture model was estimated with EM algorithm to compute the two main clusters according to bright and dim lighting conditions. And then an unsupervised K-means was implemented so as to determine a pixel whether it is from the red barrel with pre-initialized means limited by color statistics from EM algorithm. The output of the color segmentation was a logical image where true (1) pixels are red and false (0) are the rest [1].

4. Postprocessing of data

The logical output from the segmentation was then post-processed by shape context statistics. Since the pixels from detected barrel might well be from some noise or missing some holes. We need to filter out the noise and also fill in the holes in the detected area of red barrel. MATLAB built-in function `regionprops` can provide informations for the detected area in the image such as the center, area, bounding box and also the main orientation.

The parameters in statistics of shape below were considered and tested:

1. Filled area to bounding box area.

2. Height to width aspect ratio of the bounding box.

The barrel might appear in the image with an orientation angle, and the bounding box can also be tilted based on the major axis rotation of the box using the orientation statistics information.

5. Learning of Depth

After initial selection of region of interest, the bounding boxes around the barrel can be used to compute the focal length as initial attempt. In practice, we need to use the detected area width to estimate focal length, since we will use our train parameters to estimate the depth in the test. These two estimation should be consistent with each other.

After segmentation, the bounding boxes were computed automatically as the following equation

$$d = f \times \frac{W}{w}$$

Since the actual width of the barrel never changes and always can be seen in the image, we can omit this term and only focus on the w which is the width in pixels of the detected barrel region. Here the focal length f is already known as 1 (unit: meters/pixels) after training the calibrated depth.

6. Results

Here are the results of test images. In some dim lighting condition, the barrel cannot be detected. Others are good. The two barrels scenario was not considered in the algorithm.

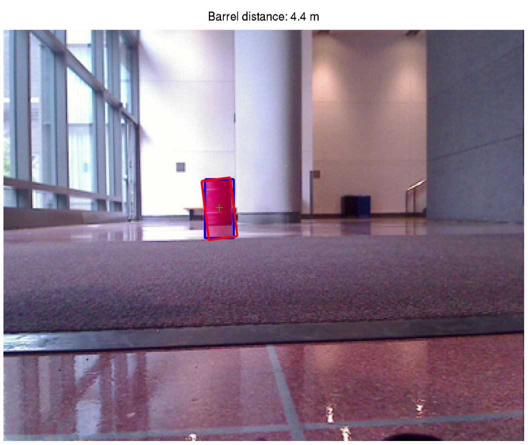

Figure 1. Result 1 from test dataset

Figure 2. Result 2 from test dataset

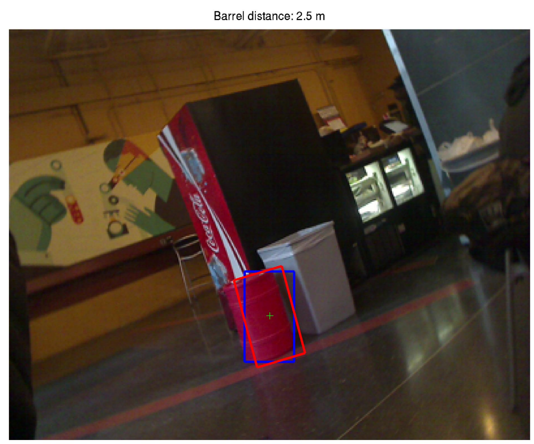

Figure 3. Result 3 from test dataset

7. Conclusion

In this project, the Gaussian mixture model (GMM) is combined with the K-means. The GMM is easy to be out of control when setting cluster number too high and also slower than K-means. Hence, for the final testing kmeans is the main method. One problem of kmeans is the its unstability. The same image might have different result with the same K-means initialization. It can be one improvement in the future work. Besides, Lab color space was used to make the segmentation lighting invariant and also set the intensity value as an additional classification.

8. Acknowledgement

Thanks to Professor Lee and TAs. Thank you for understanding my late submission since my interview in CA took my whole last week. Thank you so much.

References

[1] D. Lee. Lecture notes for ese 650: Learning in robotics, 2014.

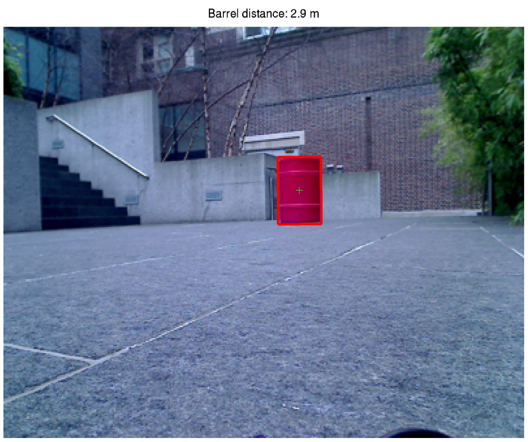

Figure 4. Result 4 from test dataset

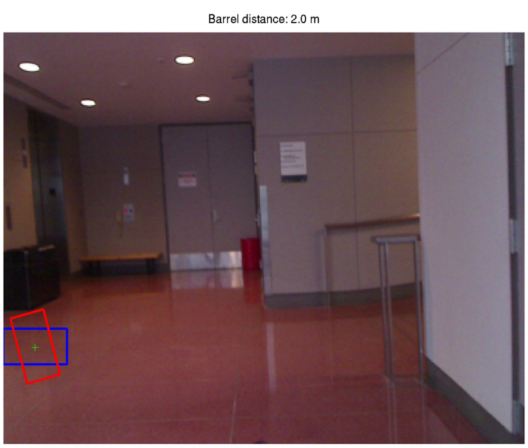

Figure 5. Result 5 from test dataset

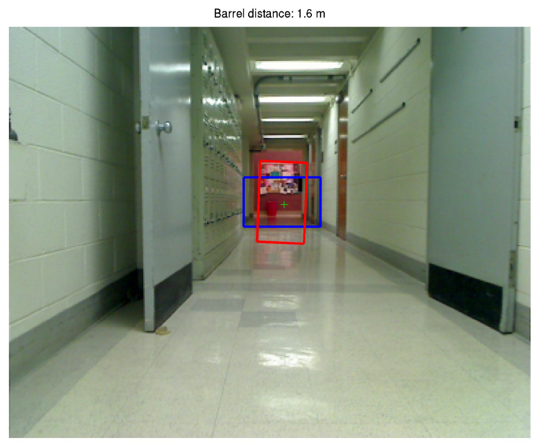

Figure 6. Result 6 from test dataset

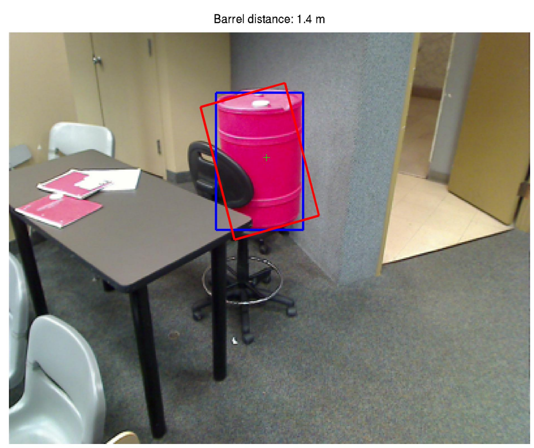

Figure 7. Result 7 from test dataset