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Project 3: Color Segmentation.

The objective of the project is to estimate a Gaussian model for Buoy and develop a Buoy detection function based on the color model. The following steps were involved in the Color Segmentation project:

Part 0:

- **Data Preparation** – In order to fit a color model of a buoy, I had to sample the data. So, I divided the video sequence (*detectbuoy.avi*) into training and testing frames - where the training frames were used to generate the sample data and fit a color model and the testing frames were used to evaluate its performance. The Cropped Buoys are the cropped buoy images from the training frames, I manually cropped the frames in-order to get only the buoy, multiple images of the same colored buoys are taken to ensure that all the buoy are included and to minimize the error rate.

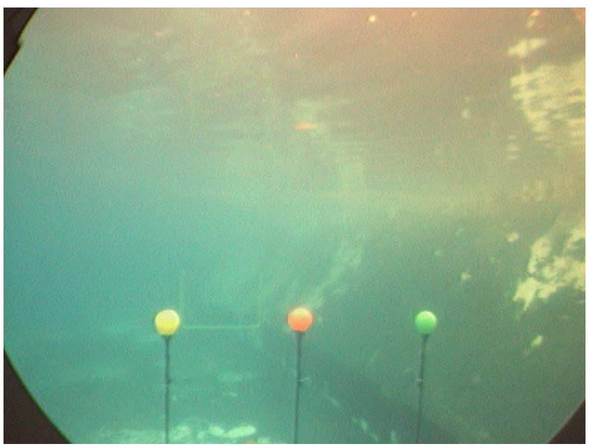


Fig (1a) – Training Frame

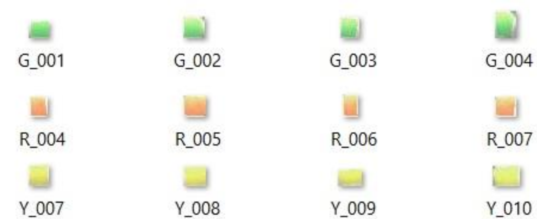


Fig (1b) – Cropped Buoys

- **Average color histogram** - For each colored buoy, I computed the average color histogram for each channel of the sampled images (RGB image) using *'averagehistogram.m'*. The histogram for All three colors along with individual channels are shown in Fig 2a, 2b & 2c.

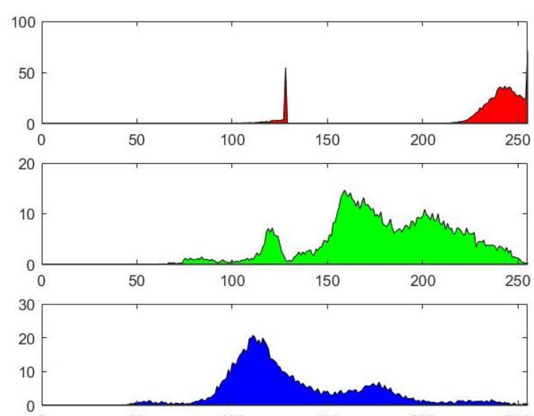


Fig (2a) – Histogram for Red Buoy (R_hist)

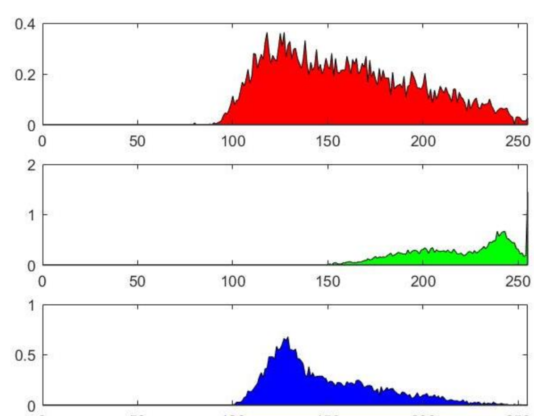


Fig (2b) – Histogram for Green Buoy (G_hist)

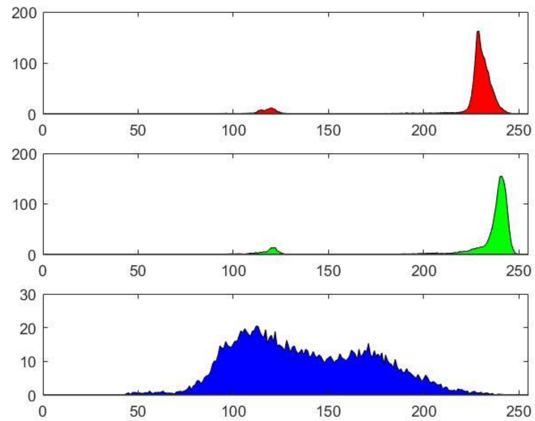


Fig (2c) – Histogram for Yellow Buoy (Y_hist)

- **<u>Color distribution of the buoys using a 1-D Gaussian model</u>** – Color Distribution is used to visualize the data for each channel of the sampled image (RGB image). The script (*estimate_color.m*) were used to get the mean and standard deviation, which were used in the detect buoy script. After successful results from the estimate files for each color, the mean, standard deviation and using normal probability distribution function 1-D Gaussian model is computed.

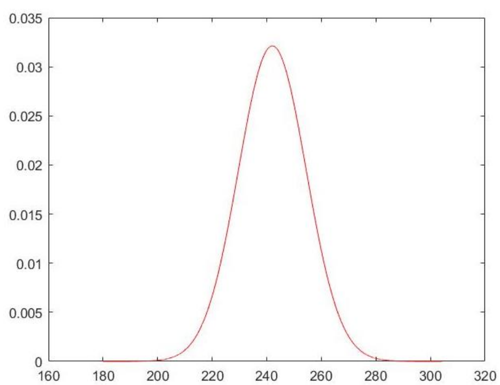


Fig (3a) – 1-D Gaussian Model (Gauss1D_red)

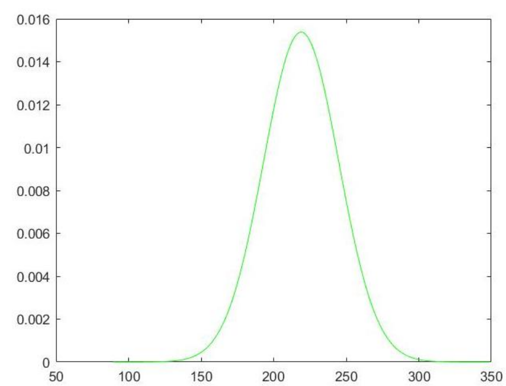


Fig (3b) – 1-D Gaussian Model (Gauss1D_green)

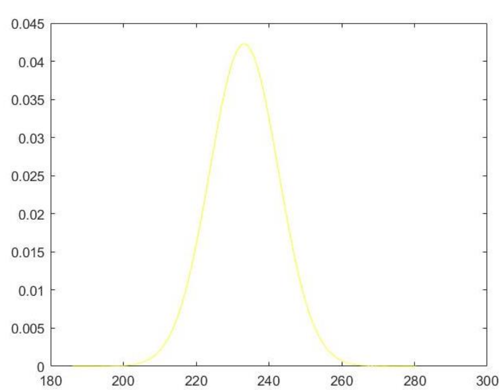


Fig (3c) – 1-D Gaussian Model (Gauss1D_yellow)

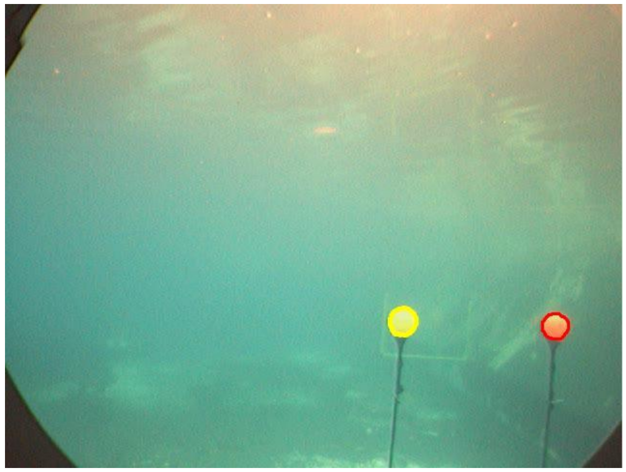
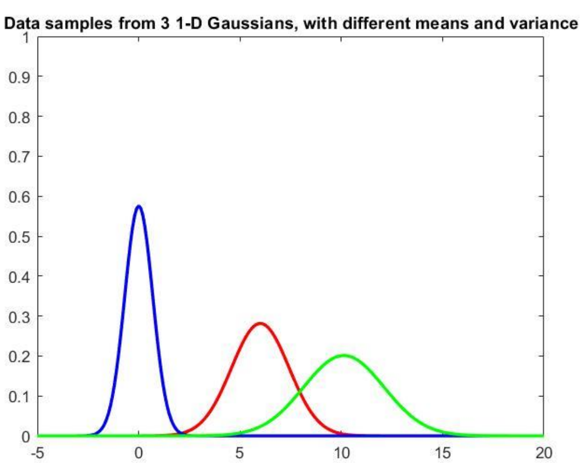
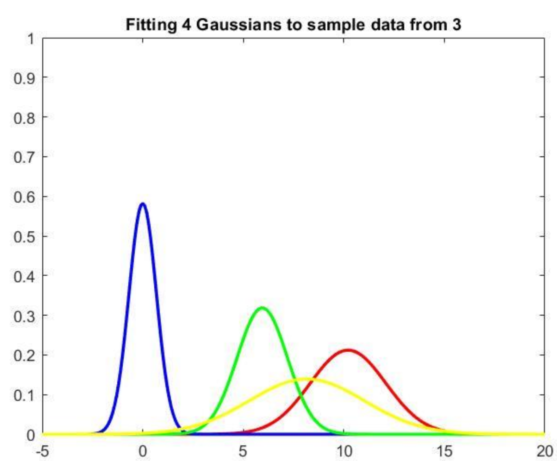


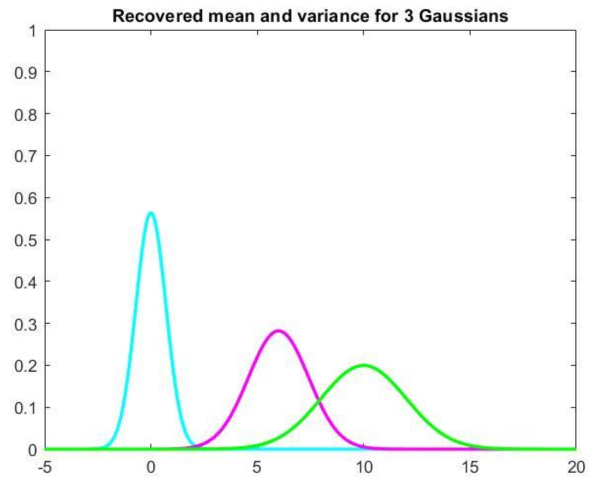
Fig (3d)- Detect Buoy using 1D gaussian

Part 1:

- **Gaussian Mixture Models (GMM) and Maximum Likelihood Algorithm** –
  - A Gaussian mixture model is a probabilistic model that assumes all the data points are generated from a mixture of a finite number of Gaussian distributions with unknown parameters. One can think of mixture models as generalizing k-means clustering to incorporate information about the covariance of the data as well as the centers of the latent Gaussians.
  - Three 1-D gaussians with different means (mu) and variances (sigma) are generated using normal probability distribution. The expectation maximization algorithm is implemented to recover the model parameter for the 3 gaussians.
  - Expectation maximization is a well-founded statistical algorithm to get around this problem by an iterative process. First one assumes random components (randomly centered on data points, learned from k-means, or even just normally distributed around the origin) and computes for each point a probability of being generated by each component of the model. Then, one tweaks the parameters to maximize the likelihood of the data given those assignments. Repeating this process is guaranteed to always converge to a local optimum.







Part 2:

- **<u>Color Model Learning</u> –**
    - We extended the Expectation Maximization concept for clustering and the color segmentation. The GMM model parameters were computed for each color channel and then were used to segment the buoy for each color. The probability distribution was calculated with the binary images to create a mask for the segmentation.
    - Then, applying the learning process by calculating the score for segmenting each buoy i.e. red, yellow and green. we re-adjusted the search window for the color set to carry the segmentation process.
    - Then the contours are calculated for each of the colored buoy after the search window is re-adjusted. This process is carried out for all the frames in the testing set and the plot is drawn over the image to detect the buoy with the contour boundary.

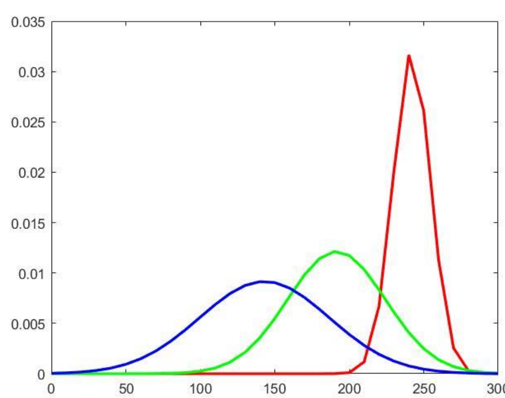


Fig (4a) – 3 1D Gaussian Model (EM_red)

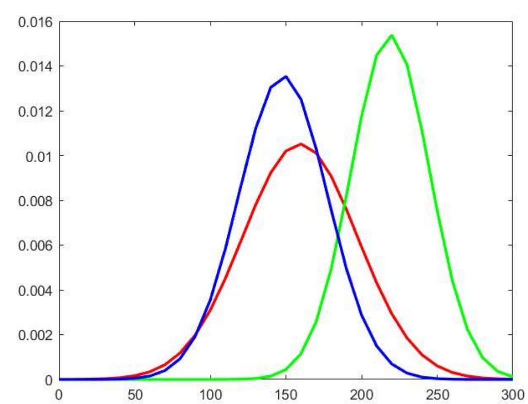


Fig (4b) – 3 1D Gaussian Model (EM_green)

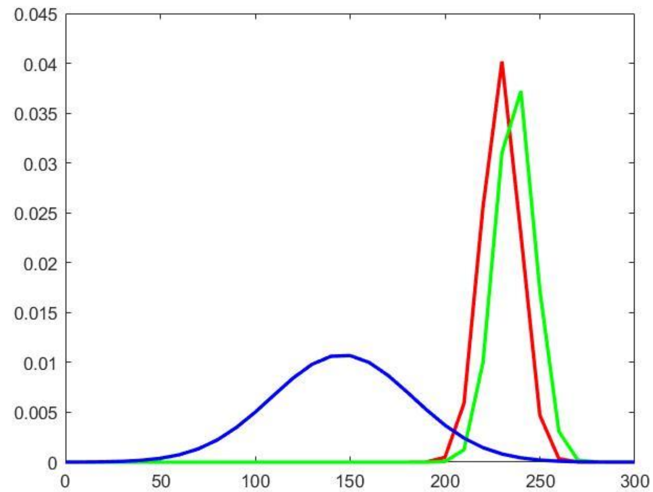


Fig (4c) – 3 1D Gaussian Model (EM_yellow)

Part 3:

- **Buoy Detection** –
    - Here we detected the buoy with the help of the color model parameters and detect the buoy based on the color. We have converted the buoy images to binary and then detected the blob, on which mask was applied to segment it.
    - Then we applied the contour on the detected buoy of the same color as of the buoy. The outputs are stored in the output folder for Part 3.
    - The output images where the red and yellow are detected, and the contours are drawn around them.

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Fig (5a) – Binary Image of the Buoy

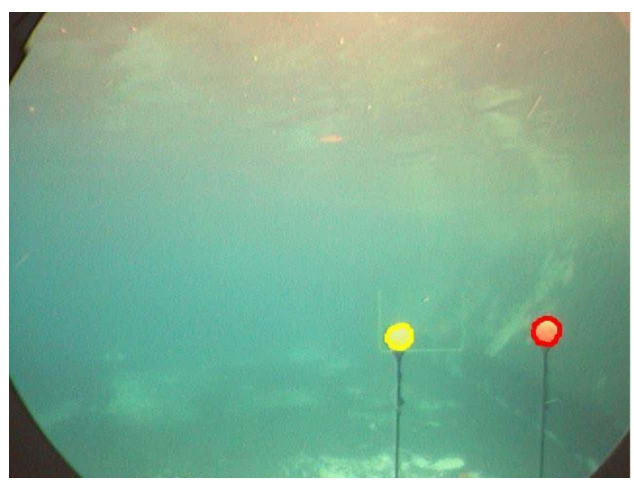

Fig (5b) – RGB Image of the buoy detection

EXTRA CREDIT

- **For the Color Segmentation scheme, used color spaces other than RBG.**
  - Using the RGB color space to segment these images was quite difficult as the RGB values face difficulties when the images have variations in lighting. For example, the buoys have slightly different RGB values depending on how the light from the surface hits them. A shadow would cause a dark red and light would create a brighter red. Both colors have very different RGB values.
  - The major difficulty was in heuristically experimenting threshold values to determine probability ranges of the different colored buoys. In contrast, the use a color space such as HSV would be more adaptive to the changes in the images such as lighting, shadow or any such noises.
  - The hue would stay relatively constant for the buoys, the differences in lighting would be represented through the value component and the "colorfulness" of each color through the saturation component. The hue and saturation values remains stable, despite the changes in lighting. This would make it much easier to detect buoys as there would be a more defined region for the buoy

- **Alternative color space representation**
  - An alternative to the conventional, RGB and HSV color space would be RGBY (Red Green Blue Yellow). This color space would add an additional value to the image as it includes a yellow layer. This additional yellow layer would provide many benefits over the traditional RGB space. First and foremost, it would provide clear identification of the yellow color.
  - One issue that I faced when running the 3D Gaussian was false detection of the green buoy. Since yellow is a combination of red and green layers, sometimes the yellow buoy would be recognized as a green buoy if the green tint was too high.
  - Additionally, the addition of the yellow layer would allow for the noise that occurs from sunlight (and other light sources) since it is generally a yellow tint. This could help with the problem we faced where the RGB values would change based on the light, as it would simply adjust the yellow more than the RGB values.

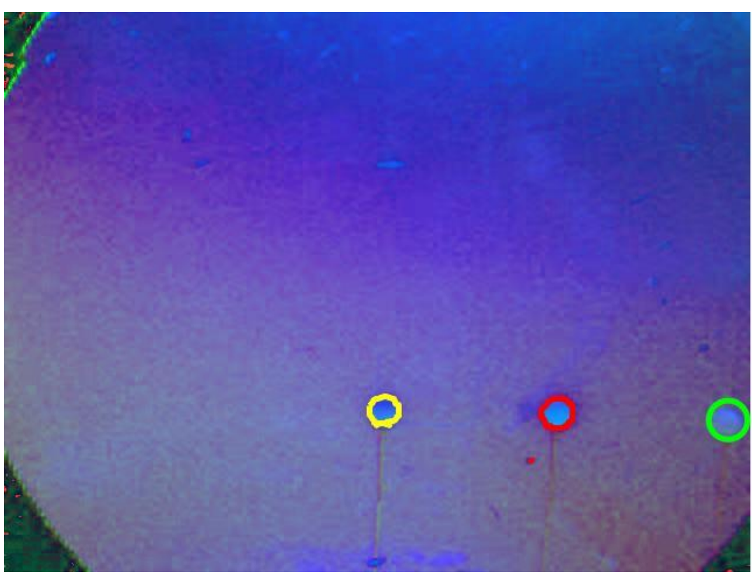

Fig (6) – Buoy detection in HSV space

References:

1. http://www.cs.ubbcluj.ro/~csatol/gep_tan/Bishop-CUED-2006.pdf
2. Video Lectures and presentation slides of Perception for Autonomous Robots.
3. Multimedia and Signal Processing by Zhaoxia Fu, Liming Wang. Chapter: Color Image Segmentation Using Gaussian Mixture Model and EM Algorithm