Image Segmentation using unsupervised learning

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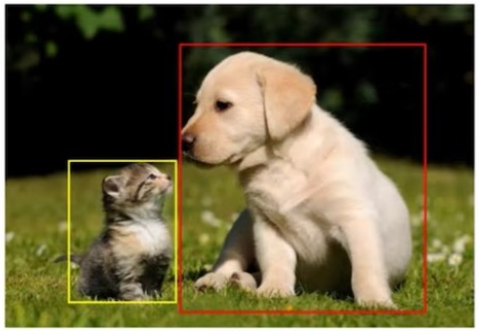
Problem Statement

- Project aims to investigate the use of Unsupervised learning techniques for the problem of image segmentation.
- We investigate the use of K means , Gaussian Mixture Models and convolutional neural networks, and a combination as an ensemble.

Introduction



Object Detection

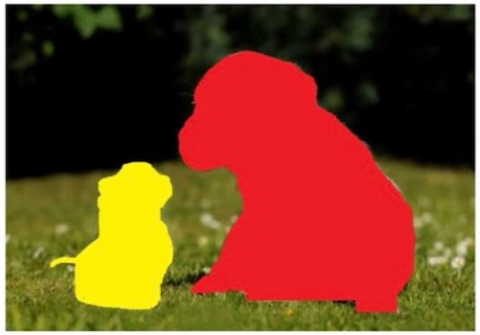


Image Segmentation

- Segmentation is the process of identifying distinguishable regions in an image
- This is performed based on the properties of pixels
- Segmentation using supervised learning works on a dataset of trained features.
- Hence, our project will focus on an investigation of various latest unsupervised image segmentation techniques performed in the field of deep learning.

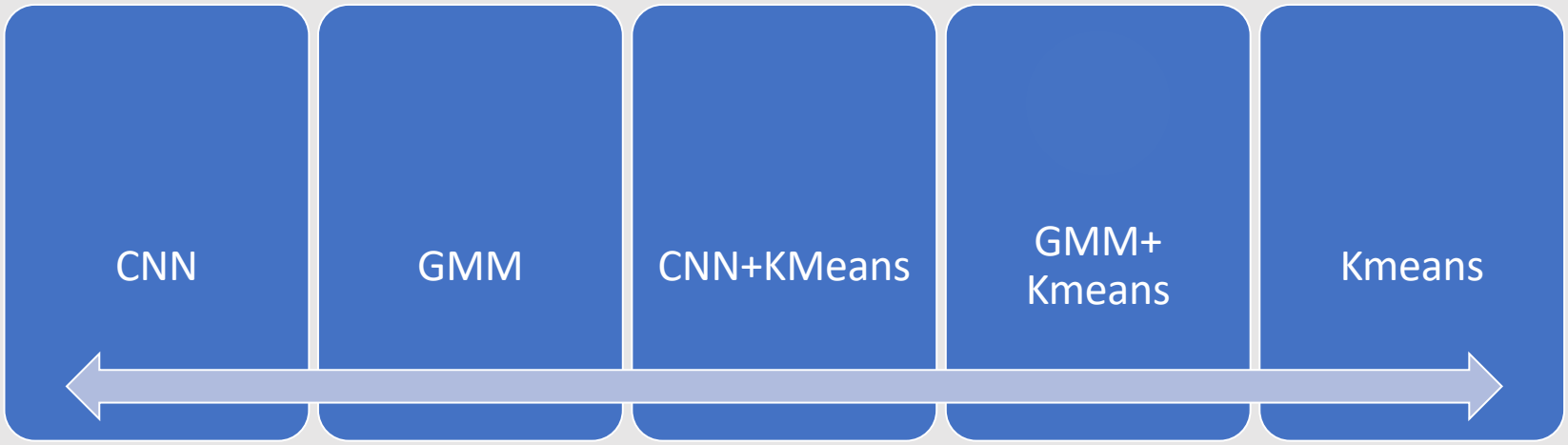
Existing Work

- Kanezaki et al. [1] studied the use of **convolutional neural networks** (CNNs) for **unsupervised** image segmentation. The proposed CNN architecture assigns labels to pixels that identify the cluster to which the pixel belongs. To identify a reasonable label assignment solution. the suggested approach minimizes the combination of similarity loss and spatial continuity loss.
- Unsupervised segmentation is performed by Xia et al.[5] by estimating segmentation from an input image and then recovering the input image using the estimated segmentation. As a result, identical pixels are assigned to the same label, even when the boundary of each segment is not estimated.
- Croitoru et al. [6] proposed an unsupervised segmentation. Their method uses deep neural network techniques to conduct binary foreground/background segmentation and is based on deep neural network techniques. The system is built to learn from multiple generations of teachers and students. In every generation, the teacher does unsupervised object discovery and then transfers the objects to the student pathway for training. Multiple students are trained using different deep network architectures at each generation to ensure greater diversity.

Research Questions

- Can unsupervised convolutional neural networks learn enough structure from data to generate good quality segments?
- Is spatial continuity important to generate good quality clusters?
- Can we improve results from CNN and GMMs using K-means?

Proposed Methodology



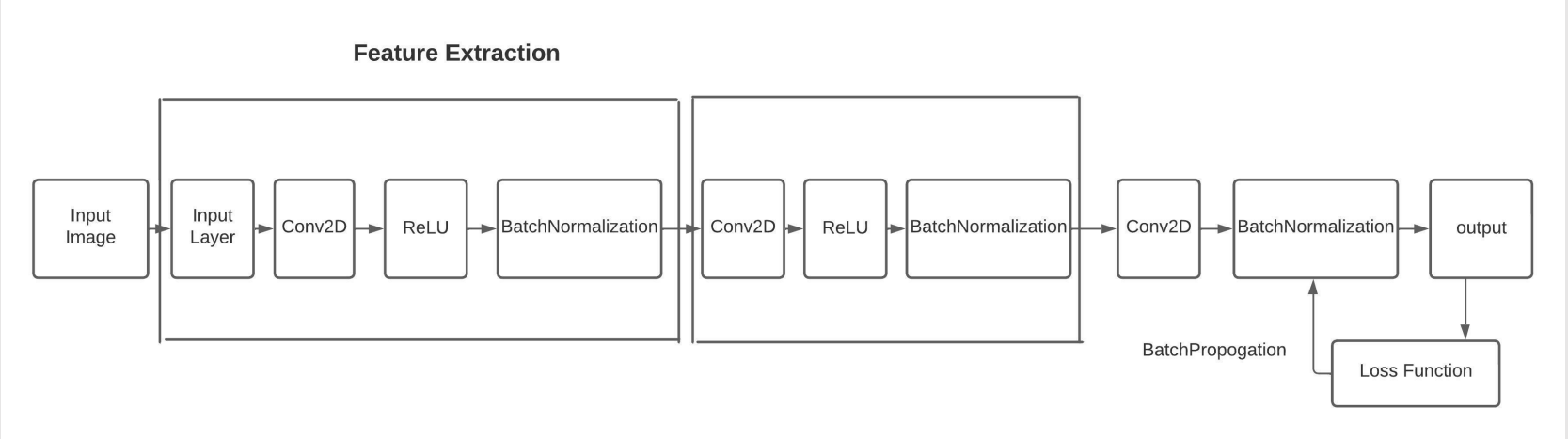
Loss function

- Cross Entropy Loss function
- Weighted average of Cross Entropy Loss and spatial discontinuity loss given by:

$$L = \underbrace{L_{\text{sim}}(\{\boldsymbol{r}'_n, c_n\})}_{\text{feature similarity}} + \mu \underbrace{L_{\text{con}}(\{\boldsymbol{r}'_n\})}_{\text{spatial continuity}},$$

CNN Architecture

CNN Architecture



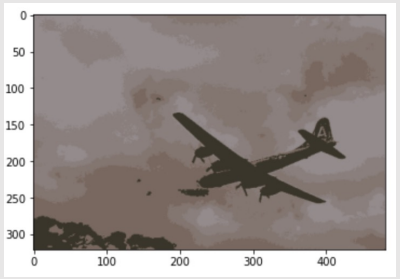
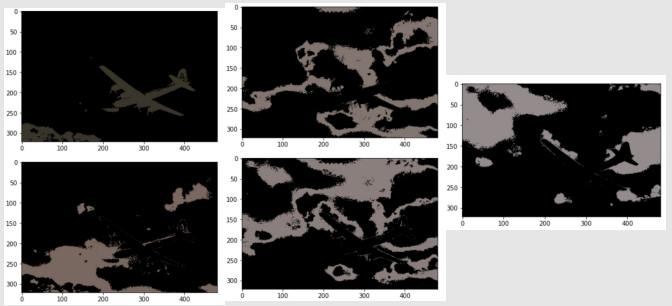
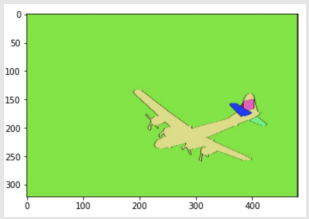


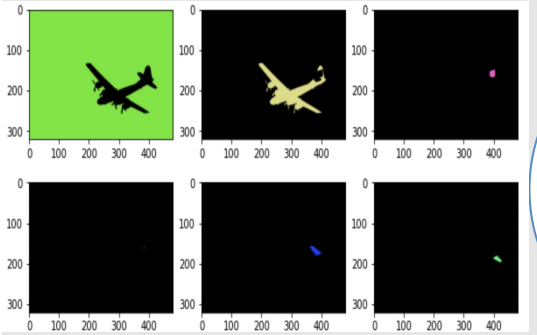
Image with Segmentations in single image



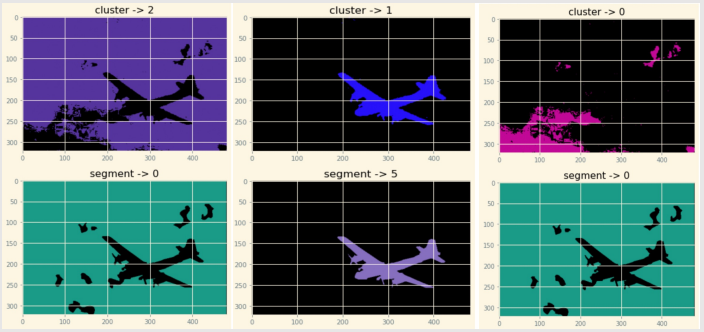
Creating Images with Each Segment



Segregating Ground Truth Image into image with each segment

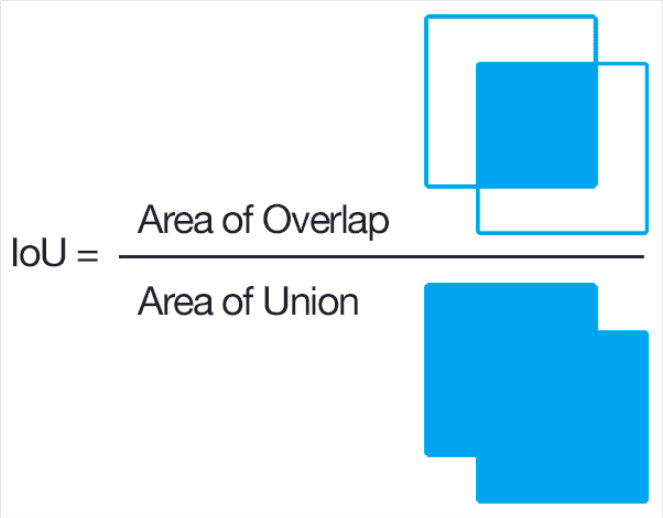


Comparing each Segmented cluster with Ground Truth Segments



Evaluation Metrics

- We use the IoU (Intersection over Union) to evaluate the segmented images.

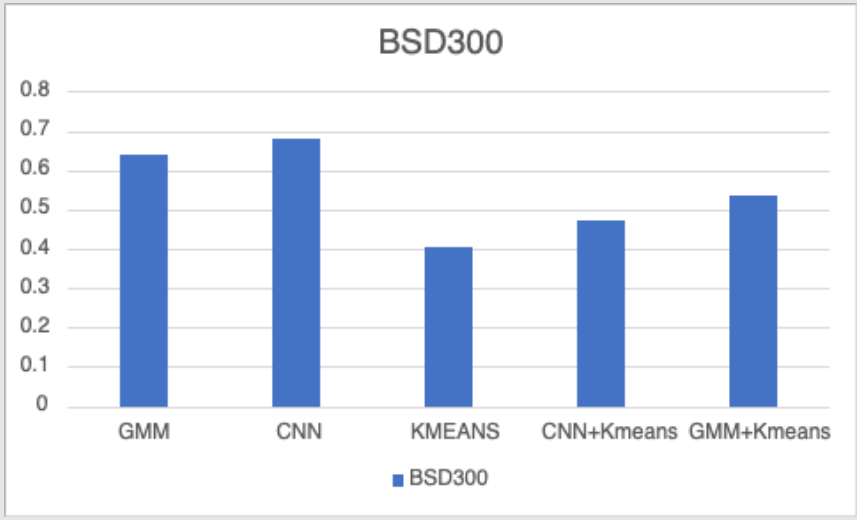


Results

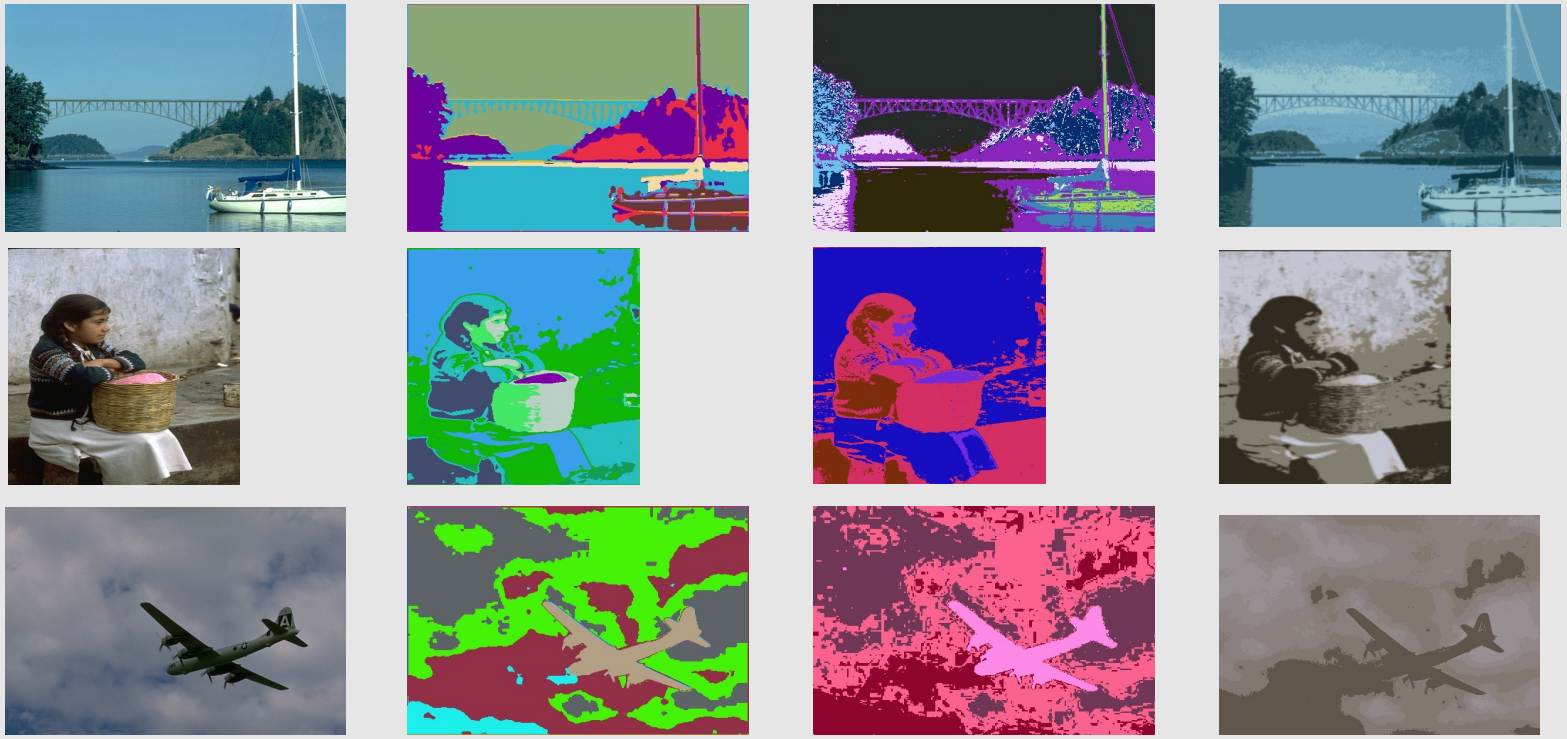
	GMM	CNN	KMEANS	CNN+Kmeans	GMM+Kmeans
25098	0.63	0.74	0.584866469	0.470433972	0.606763285
3096	0.78	0.81	0.616189137	0.373132573	0.535294767
35058	0.36	0.5	0.234985737	0.333206719	0.457345126
22090	0.72	0.74	0.33427856	0.63567846	0.460965489
23025	0.69	0.81	0.373537269	0.643854966	0.631178954

Results

	GMM	CNN	KMEANS	CNN+ Kmeans	GMM+ Kmeans
BSD300	0.64	0.68	0.40	0.47	0.53



Segmented Images comparison

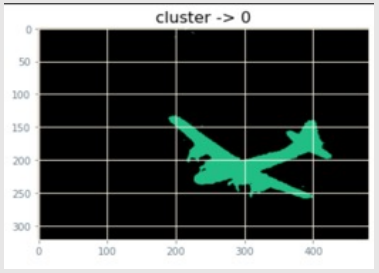


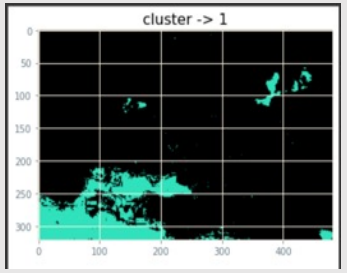
Input Image | CNN segmentation | GMM segmentation | K-means segmentation

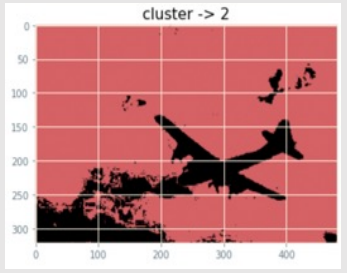
CNN vs GMM cluster comparison

Cluster segments

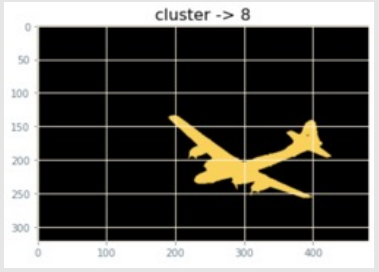
GMM clusters

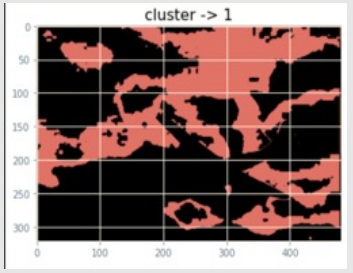


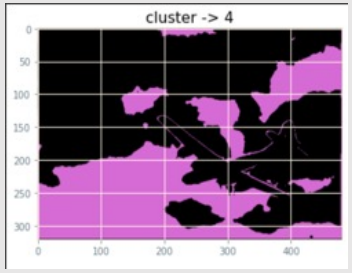




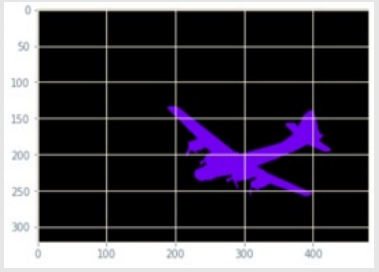
CNN clusters

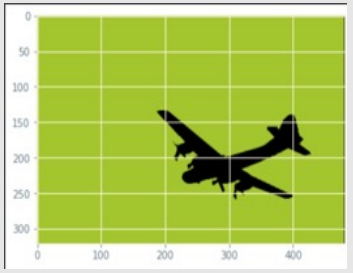


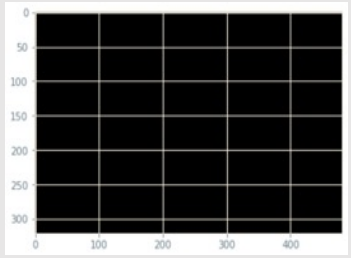




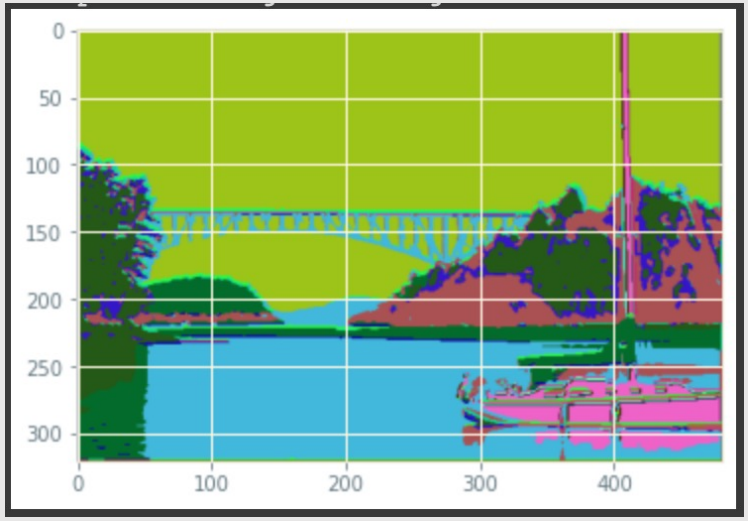
Ground Truth Segments







Loss function comparison



Cross Entropy Loss

Weighted Average of Cross Entropy Loss and Spatial Discontinuity Loss

More consistent clusters when we include Spatial Discontinuity Loss

Conclusion

- Convolutional neural networks outperform other image segmentation methods like Gaussian Mixture models and K-Means
- Refining results from CNN and GMMs with K-Means results in inferior segments
- Spatial continuity loss plays an important role in quality of clusters

Conclusion

- Performed image segmentation using OpenCV and Pytorch.
- Evaluated the performance across CNN and Gaussian Mixture models and both as an ensemble
- Investigated the importance of using Spatial Discontinuity Loss function over Cross Entropy Loss function.
- Proposed a novel metric to evaluate Jaccard index(IoU) using masked layers of images of different segmented clusters.

THANK YOU