Enhancing Satellite Ship Classification: A Comparative Analysis of HOG Feature Descriptor Outperforming PCA

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Aim and Scope

Our aim is to evaluate and compare the effectiveness of HOG (Histogram of Oriented Gradients) and PCA (Principal Component Analysis) feature descriptors in the classification of ships via satellite images.

Our scope of classification focuses on grayscale images with size of 80x80. We define our positive class as a single ship and negative as some lands or sea images. Then, we apply HOG and PCA on these datasets and pass it into 3 different models SVM, Logistic Regression, MLP Classifier. Our application envisions serving marine detection for missile launch, thus we emphasize precision as the primary metric.

We hypothesize HOG will show a greater boost in our precision in 3 classification algorithms compared to PCA. This is because HOG is strong at capturing overall spatial information of the object in the image, while PCA focuses on capturing the maximum variability in pixel intensities across our image. We will take these into account to process our experiment.

Features

Preprocessing: Our datasets from Kaggle consist of 1000 “ship” and 3000 “not ship” images that will be labeled, converted into numpy.ndarray format, and be normalized by our existing maximum pixel value 255.

Feature Engineering: Next, we generate 2 different types of datasets. In specific, a PCA and a HOG representation of our original dataset.

[1] PCA : First, we reshape each image into a 1D array, and we find an optimal value n=800 of components such that the principal component captures the most significant patterns to represent ships and land structures. Then, we use that value to calculate our newly reduced features. This will be our first kind of dataset.

[2] HOG : First, we take each 80x80 image, define a cell size of 8x8 to get a total of 10x10 cells. Now, for each cell, we generate a histogram of 9 bins to capture the distribution of gradient orientations(direction in which grayscale changes). Each bin represents how much intensity of gray level changed for each orientation. Then, perform these operations in a group of 4 cells and normalize each bin with L2 normalization. This results in a compact representation of the image packed in a feature 1D vector of size 5184.

Model Selection :
Next, we feed these 2 datasets into these 3 models

[1] linear SVC with 0.9 penalty with max iteration of 100.
[2] Logistic Regression with 0.9 penalty with max iteration of 100.
[3] Multi Perceptron with 2 hidden layers of 10 neurons, Relu activation function.

Analysis of the Output

We summarize each model's precision in terms of predicting a ship is present below.

Models/ Feature engineering	PCA	HOG
Linear SVC	0.52	0.93
Logistic regression	0.76	0.98
MLP	0.85	0.97

From the table, we see a few observations. First, complex algorithms were able to capture complex features in the image well with the help of non-linearity, compared to linear models. Second, PCA + SVM gives the lowest precision, this may indicate generating new linear combinations results in losing important features that distinguish ships/no ships. It could also imply linear lines were struggling to find a good decision boundary. Finally, we see that applying HOG to models significantly increases precision. This indicates HOG is effective in capturing spatial information of ships.

Conclusion and References

The observations from the table highlights the importance of model complexity and introducing non linearity functions. More importantly, feature descriptors play an important role in representing an image's most distinct features. In addition, they also make algorithms to have less complexity in computation. There is still room for improvement. We may incorporate 2 more channels as we are limiting the scope to grayscale. And, we may need to test more other models with HOG to prove our correctness on our hypothesis.

References

[1] In Depth: Principal Component Analysis
[2] Kaggle : Identifying Ships in Satellite Images
[3] Vehicle Detection with HOG and Linear SVM
[4] HOG Feature Vector Calculation
[5] Deep Learning with Python - Francois Chollet
[6] HOG feature descriptor based PCA with SVM for efficient & accurate classification