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EXERCISE: Ellipse Counter using Convolutional Neural Network

The task involved building a Machine Learning model that processes an image containing elliptical, coloured blobs and correctly counts them amongst clutter in the form of coloured polygons.

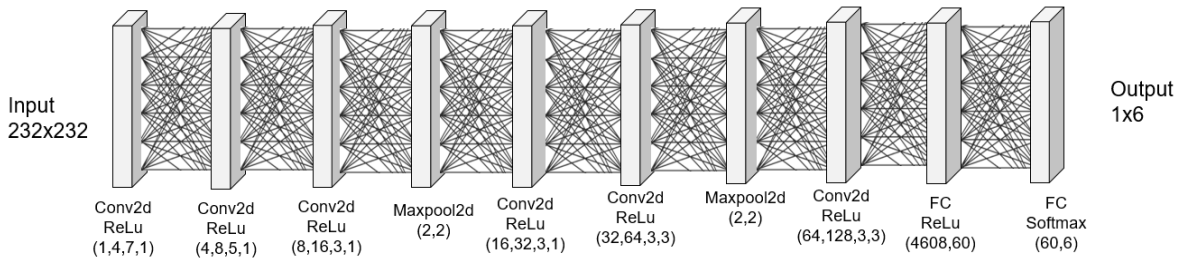
My approach for the problem was the use of Convolutional Neural Network model using Pytorch machine learning framework. The input features of the model is the image and the output feature of the model is the count of the number of elliptical blob (0 - 5) in the image.

Procedure:

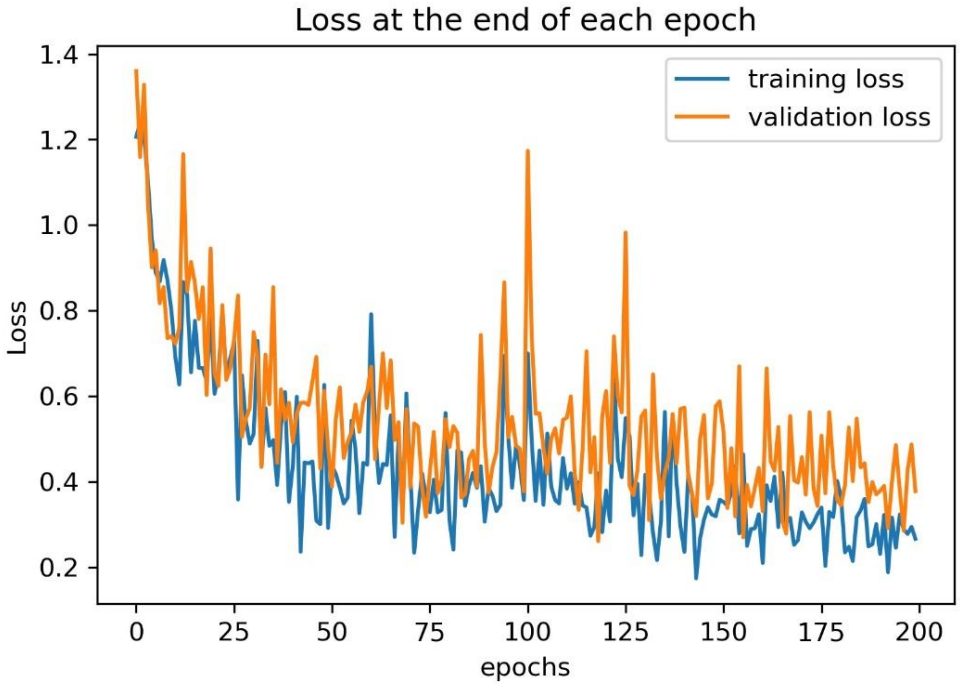
1. Data Augmentation and Preprocessing Stage

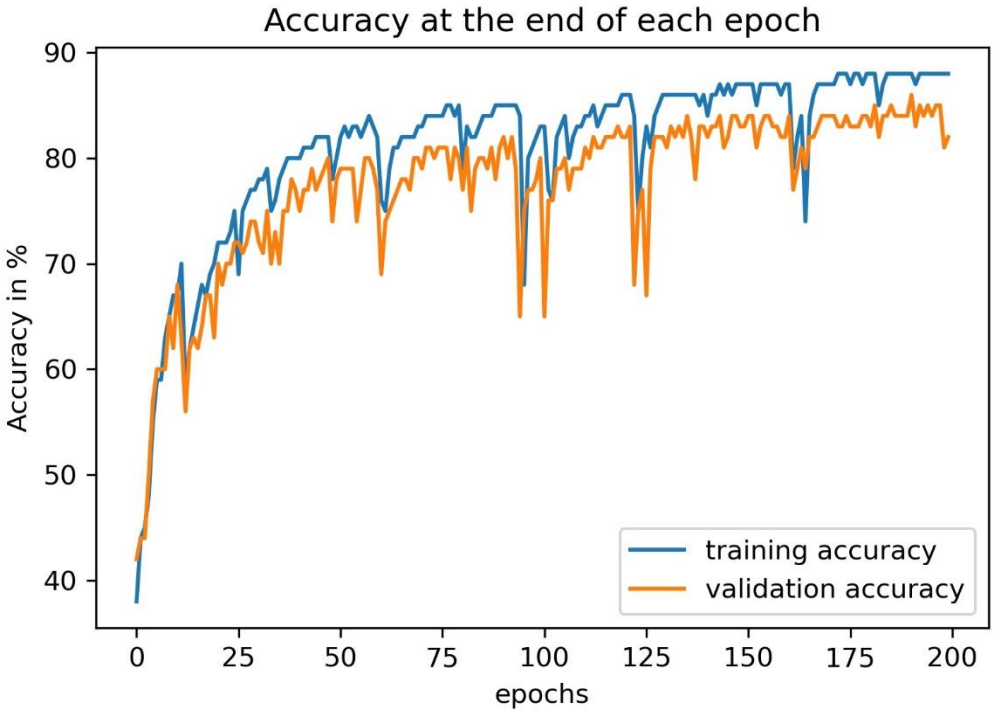
The data was imported from the folder and transformed by conversion to single channel grayscale, padding, random rotation and normalization. The data was augmented by rotation 45^o, 90^o, 180^o and 270^o. This created an additional 40,000 images, hence 50,000 total number of images. The dataset was splitted into training set (80%) and test set (20%) .

2. The CNN Model developed is as shown in the image below. The first three layers are 2D convolutional neural network with 4, 8, 16 filters respectively using ReLU activation function. This is followed by a maxpool2d layer and two additional layers of 2D CNN with 32,64 filters respectively and ReLU activation function. A maxpool2d layer precedes the last CNN model of 128 filters using ReLU activation function. The output of this is flattened and passed to a fully connected layer of ReLU activated neurons, and lastly, a fully connected layer using softmax activation function for the output classification.



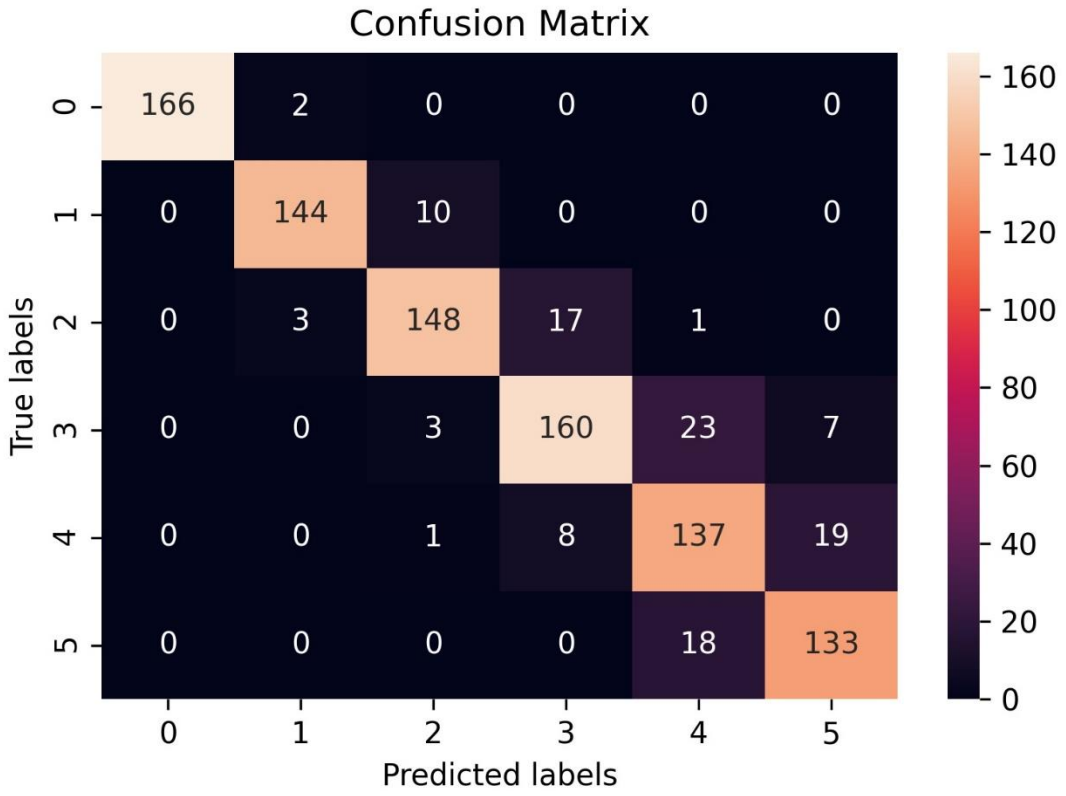
3. The model was trained for 200 epochs, using cross entropy criterion and Adam optimizer. The loss and accuracy of the training and evaluation was taken simultaneously and they are shown in the figure below.





4. The model was saved at the epoch with the best validation accuracy 86.02%, at same epoch the training accuracy is 88.34%

5. The model was tested with a set of 1000 images with an accuracy of 88.8%. The confusion matrix for the test is shown below.



Generally, the number and overlapping of the polygons greatly reduces the accuracy of the model. Fromt the confusion matrix, it can be seen that the model performed better on the case of 0 elliptical blobs than in the case of 5 elliptical blobs. Cases where the shapes overlapped would also challenge the model accuracy.

To understand what happens at each convolutional layer, the table below shows the concatenation of the filters in each convolutional layer and a sample of output image from this layer. By looking at the filters for a particular layer, it is obvious that different filters are learning different information. But as we go deeper, the number of filters in each layer increases and it is not visually possible to see what the filter is learning as they tend to capture higher level infromation. We can see from the column showing sample image that the filters are trying to learn features such as the edges, angles, boudaries, the background in the image.

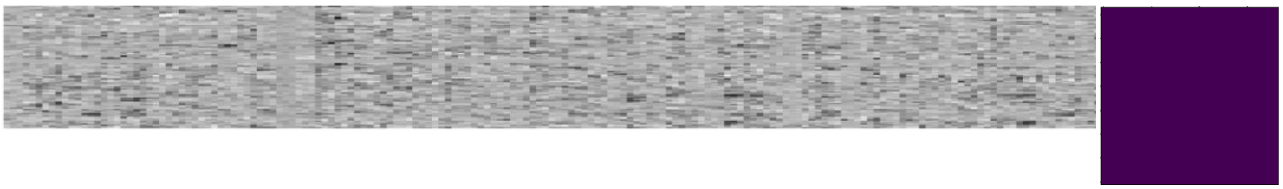
1st Conv2d Filters

2nd Conv2d Filters

3rd Conv2d Filters

4th Conv2d filters

5th Conv2d filters



6th Conv2d filters

After realizing the model that predicts the number of ellipse, transfer learning can be used to fine-tune this model in order to predict the number of polygon.

This model can be improved further by adding an additional convolutional layer before flattening and addition of fully connected layers.