Experiment No. 6
Design and implement a CNN model for Object Detection using CIFAR-10 dataset
Date of Performance:
Date of Submission:

Aim: Design and implement a CNN model for Object Detection using CIFAR-10 dataset.

Objective: Ability to design convolution neural network to solve the given problem

Theory:

A Convolutional Neural Network (CNN) is a type of Deep Learning neural network architecture commonly used in Computer Vision. Computer vision is a field of Artificial Intelligence that enables a computer to understand and interpret the image or visual data.
When it comes to Machine Learning, Artificial Neural Networks perform really well. Neural Networks are used in various datasets like images, audio, and text. Different types of Neural Networks are used for different purposes, for example for predicting the sequence of words we use Recurrent Neural Networks more precisely an LSTM, similarly for image classification we use Convolution Neural networks. In this blog, we are going to build a basic building block for CNN.

In a regular Neural Network there are three types of layers:

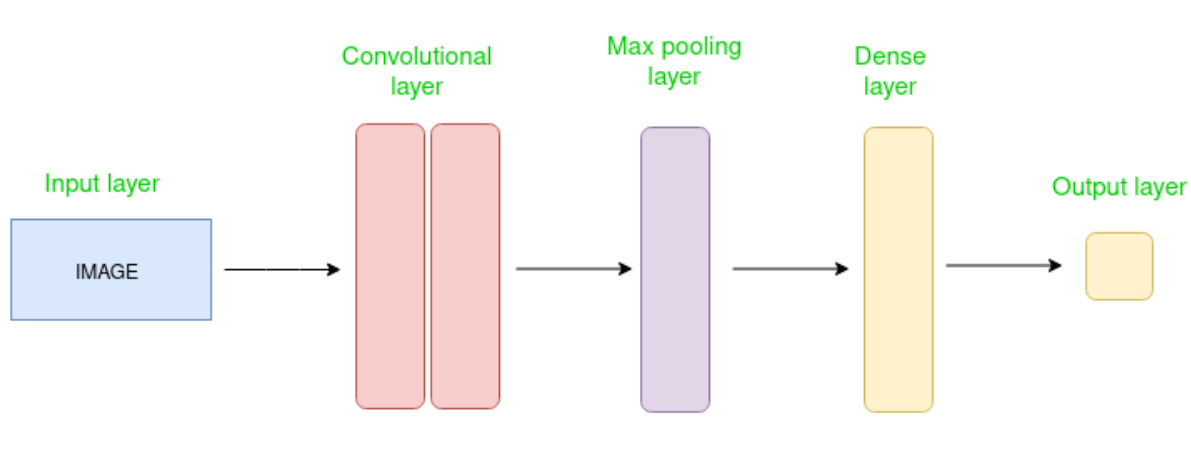
Input Layers: It's the layer in which we give input to our model. The number of neurons in this layer is equal to the total number of features in our data (number of pixels in the case of an image).
Hidden Layer: The input from the Input layer is then feed into the hidden layer. There can be many hidden layers depending upon our model and data size. Each hidden layer can have different numbers of neurons which are generally greater than the number of features. The output from each layer is computed by matrix multiplication of output of the previous layer with learnable weights of that layer and then by the addition of learnable biases followed by activation function which makes the network nonlinear.
Output Layer: The output from the hidden layer is then fed into a logistic function like sigmoid or softmax which converts the output of each class into the probability score of each class.
The data is fed into the model and output from each layer is obtained from the above step is called feedforward, we then calculate the error using an error function, some common error functions are cross-entropy, square loss error, etc. The error function measures how well the network is performing. After that, we backpropagate into the model by calculating the derivatives. This step is called Backpropagation which basically is used to minimize the loss.

Convolution neural network:

Convolutional Neural Network (CNN) is the extended version of artificial neural networks (ANN) which is predominantly used to extract the feature from the grid-like matrix dataset. For example visual datasets like images or videos where data patterns play an extensive role.

CNN architecture

Convolutional Neural Network consists of multiple layers like the input layer, Convolutional layer, Pooling layer, and fully connected layers.



The Convolutional layer applies filters to the input image to extract features, the Pooling layer downsamples the image to reduce computation, and the fully connected layer makes the final prediction. The network learns the optimal filters through backpropagation and gradient descent.

Layers In CNN:

Input Layers: It's the layer in which we give input to our model. In CNN, Generally, the input will be an image or a sequence of images. This layer holds the raw input of the image with width 32, height 32, and depth 3.

Convolutional Layers: This is the layer, which is used to extract the feature from the input dataset. It applies a set of learnable filters known as the kernels to the input images. The filters/kernels are smaller matrices usually 2×2, 3×3, or 5×5 shape. it slides over the input image data and computes the dot product between kernel weight and the corresponding input

image patch. The output of this layer is referred ad feature maps. Suppose we use a total of 12 filters for this layer we'll get an output volume of dimension 32 x 32 x 12.

Activation Layer: By adding an activation function to the output of the preceding layer, activation layers add nonlinearity to the network. it will apply an element-wise activation function to the output of the convolution layer. Some common activation functions are RELU: max(0, x), Tanh, Leaky RELU, etc. The volume remains unchanged hence output volume will have dimensions 32 x 32 x 12.

Pooling layer: This layer is periodically inserted in the covnets and its main function is to reduce the size of volume which makes the computation fast reduces memory and also prevents overfitting. Two common types of pooling layers are max pooling and average pooling. If we use a max pool with 2 x 2 filters and stride 2, the resultant volume will be of dimension 16x16x12.

Flattening: The resulting feature maps are flattened into a one-dimensional vector after the convolution and pooling layers so they can be passed into a completely linked layer for categorization or regression.

Fully Connected Layers: It takes the input from the previous layer and computes the final classification or regression task.

Output Layer: The output from the fully connected layers is then fed into a logistic function for classification tasks like sigmoid or softmax which converts the output of each class into the probability score of each class.

Code:

```
import tensorflow as tf
from tensorflow.keras import datasets, layers, models
import matplotlib.pyplot as plt

# Load the CIFAR-10 dataset
(X_train, y_train), (X_test, y_test) = datasets.cifar10.load_data()
```

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# Normalize pixel values to be between 0 and 1
X_train, X_test = X_train / 255.0, X_test / 255.0

# Define class names for CIFAR-10 dataset
class_names = ['airplane', 'automobile', 'bird', 'cat', 'deer',
               'dog', 'frog', 'horse', 'ship', 'truck']

# Building the CNN model
model = models.Sequential()

# First Convolutional layer
model.add(layers.Conv2D(32, (3, 3), activation='relu', input_shape=(32, 32, 3)))
model.add(layers.MaxPooling2D((2, 2)))

# Second Convolutional layer
model.add(layers.Conv2D(64, (3, 3), activation='relu'))
model.add(layers.MaxPooling2D((2, 2)))

# Third Convolutional layer
model.add(layers.Conv2D(64, (3, 3), activation='relu'))

# Flattening layer
model.add(layers.Flatten())

# Fully connected layer
model.add(layers.Dense(64, activation='relu'))

# Output layer with 10 classes (since CIFAR-10 has 10 classes)
model.add(layers.Dense(10, activation='softmax'))

# Compile the model
model.compile(optimizer='adam',
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        loss='sparse_categorical_crossentropy',
        metrics=['accuracy'])

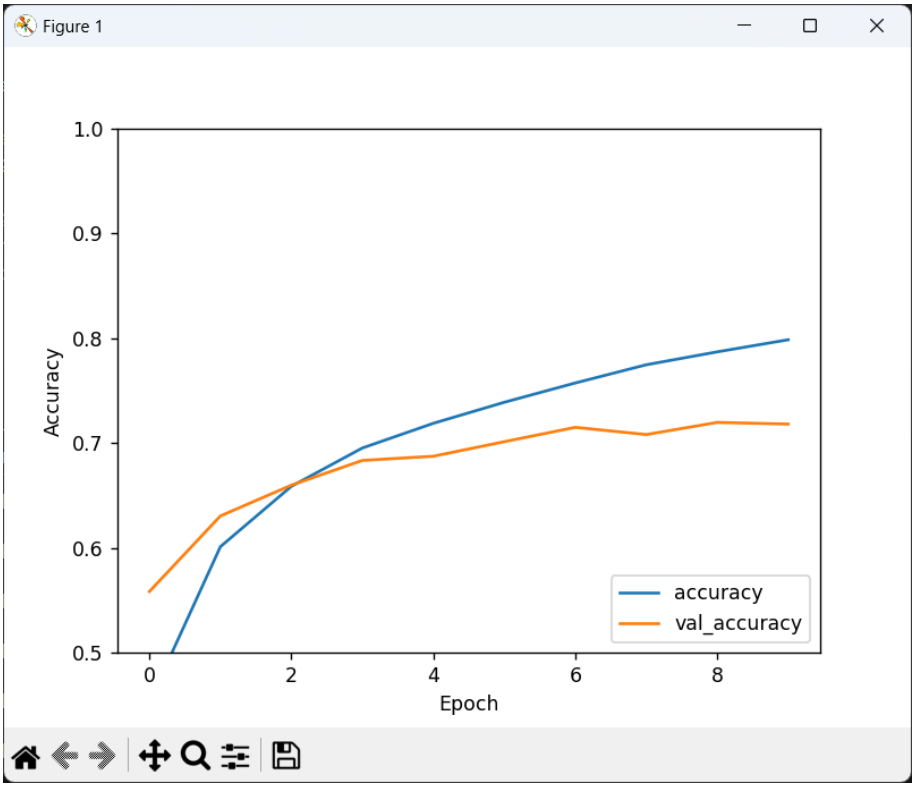
# Train the model
history = model.fit(X_train, y_train, epochs=10,
                    validation_data=(X_test, y_test))

# Evaluate the model on test data
test_loss, test_acc = model.evaluate(X_test, y_test, verbose=2)
print(f"Test accuracy: {test_acc}")

# Plot training and validation accuracy
plt.plot(history.history['accuracy'], label='accuracy')
plt.plot(history.history['val_accuracy'], label = 'val_accuracy')
plt.xlabel('Epoch')
plt.ylabel('Accuracy')
plt.ylim([0.5, 1])
plt.legend(loc='lower right')
plt.show()
```

Output:

```
To enable the following instructions: AVX2 AVX_VNNI FMA, in other operations, rebuild TensorFlow with the appropriate compiler flags.
Epoch 1/10
1563/1563 ━━━━━━━━━━━━━━━━━━━━ 7s 4ms/step - accuracy: 0.3643 - loss: 1.7138 - val_accuracy: 0.5583 - val_loss: 1.2202
Epoch 2/10
1563/1563 ━━━━━━━━━━━━━━━━━━━━ 6s 4ms/step - accuracy: 0.5829 - loss: 1.1775 - val_accuracy: 0.6304 - val_loss: 1.0588
Epoch 3/10
1563/1563 ━━━━━━━━━━━━━━━━━━━━ 6s 4ms/step - accuracy: 0.6496 - loss: 0.9958 - val_accuracy: 0.6598 - val_loss: 0.9663
Epoch 4/10
1563/1563 ━━━━━━━━━━━━━━━━━━━━ 6s 4ms/step - accuracy: 0.6986 - loss: 0.8637 - val_accuracy: 0.6834 - val_loss: 0.9062
Epoch 5/10
1563/1563 ━━━━━━━━━━━━━━━━━━━━ 6s 4ms/step - accuracy: 0.7209 - loss: 0.7951 - val_accuracy: 0.6874 - val_loss: 0.9018
Epoch 6/10
1563/1563 ━━━━━━━━━━━━━━━━━━━━ 6s 4ms/step - accuracy: 0.7411 - loss: 0.7384 - val_accuracy: 0.7013 - val_loss: 0.8808
Epoch 7/10
1563/1563 ━━━━━━━━━━━━━━━━━━━━ 6s 4ms/step - accuracy: 0.7594 - loss: 0.6799 - val_accuracy: 0.7150 - val_loss: 0.8529
Epoch 8/10
1563/1563 ━━━━━━━━━━━━━━━━━━━━ 6s 4ms/step - accuracy: 0.7787 - loss: 0.6361 - val_accuracy: 0.7081 - val_loss: 0.8588
Epoch 9/10
1563/1563 ━━━━━━━━━━━━━━━━━━━━ 6s 4ms/step - accuracy: 0.7920 - loss: 0.5903 - val_accuracy: 0.7197 - val_loss: 0.8442
Epoch 10/10
1563/1563 ━━━━━━━━━━━━━━━━━━━━ 6s 4ms/step - accuracy: 0.8010 - loss: 0.5556 - val_accuracy: 0.7181 - val_loss: 0.8712
313/313 - 1s - 2ms/step - accuracy: 0.7181 - loss: 0.8712
Test accuracy: 0.7181000113487244
```



Conclusion:

The designed CNN model effectively classifies images from the CIFAR-10 dataset with an accuracy around the expected value for such a baseline model. The convolutional layers efficiently extract features, such as edges and textures, while the max-pooling layers help reduce computation and prevent overfitting. As the network deepens, more complex features are learned. This architecture balances model complexity and performance.