Problem_1 : Design a simple DNN. Use three hidden-layers of sizes 32, 64, and 128 and display the generated DNN with the number of parameters.

Parameter Calculation:

Parameters Calculation

The number of parameters in each layer can be calculated as follows:

- For a Dense layer, the number of parameters is given by:

$$\text{Parameters} = (\text{input units} + 1) \times \text{output units}$$

Where "+1" accounts for the bias term.

1. **First Hidden Layer (32 units):**

$$\text{Parameters} = (100 + 1) \times 32 = 3232$$

2. **Second Hidden Layer (64 units):**

$$\text{Parameters} = (32 + 1) \times 64 = 2112$$

3. **Third Hidden Layer (128 units):**

$$\text{Parameters} = (64 + 1) \times 128 = 8320$$

4. **Output Layer (1 unit):**

$$\text{Parameters} = (128 + 1) \times 1 = 129$$

Total Parameters

Adding all these together gives:

$$3232 + 2112 + 8320 + 129 = 13793$$

Thus, the total number of parameters in this DNN is **13,793**.

Problem_2: Build a CNN which exactly looks like VGG16.

Parameter Calculation:

1. Convolutional Layers

The formula for calculating parameters in a `Conv2D` layer is:

$$\text{Parameters} = (\text{filter height} \times \text{filter width} \times \text{input channels} + 1) \times \text{number of filte}$$

- **Block 1:**
  - **Conv2D (64 filters):**
    - Parameters = (3 * 3 * 3 + 1) * 64 = (27 + 1) * 64 = 28 * 64 = **1,792**
  - **Conv2D (64 filters):**
    - Parameters = (3 * 3 * 64 + 1) * 64 = (576 + 1) * 64 = 577 * 64 = **36,928**
- **Block 2:**
  - **Conv2D (128 filters):**
    - Parameters = (3 * 3 * 64 + 1) * 128 = (576 + 1) * 128 = 577 * 128 = **73,856**
  - **Conv2D (128 filters):**
    - Parameters = (3 * 3 * 128 + 1) * 128 = (1152 + 1) * 128 = 1153 * 128 = **147,584**
- **Block 3:**
  - **Conv2D (256 filters):**
    - Parameters = (3 * 3 * 128 + 1) * 256 = (1152 + 1) * 256 = 1153 * 256 = **295,168**
  - **Conv2D (256 filters):**
    - Parameters = (3 * 3 * 256 + 1) * 256 = (2304 + 1) * 256 = 2305 * 256 = **590,080**
  - **Conv2D (256 filters):**
    - Parameters = (3 * 3 * 256 + 1) * 256 = (2304 + 1) * 256 = **590,080**

- **Block 4**:
  - **Conv2D (512 filters)**:
    - Parameters = (3 * 3 * 256 + 1) * 512 = (2304 + 1) *512= **1,180,160**
  - **Conv2D (512 filters)**:
    - Parameters = (3 * 3 *512 +1)*512= **2,359,808**
  - **Conv2D (512 filters)**:
    - Parameters = (3*3*512+1)*512= **2,359,808**
- **Block5**:
  - **Conv2D (512 filters)**:
    - Parameters = (3*3*512+1)*512= **2,359,808**
  - **Conv2D (512 filters)**:
    - Parameters = (3*3*512+1)*512= **2,359,808**
  - **Conv2D (512 filters)**:
    - Parameters = (3*3*512+1)*512= **2,359,808**

Total Convolutional Layer Parameters

Now let's sum up all the parameters from the convolutional layers:

- Block 1: $1,792 + 36,928$
- Block2: $73,856 + 147,584$
- Block3: $295,168 + 590,080 + 590,080$
- Block4: $1,180,160 + 2,359,808 + 2,359,808$
- Block5: $2,359,808 + 2,359,808 + 2,359,808$

Calculating these:

- Block1 Total: $38,720$
- Block2 Total: 221440
- Block3 Total: 1472328
- Block4 Total: $6,899776$
- Block5 Total: 7.079424

Summing All Convolutional Layer Parameters

Total for all convolutional layers:

$$38,720 + 221440 + 1472328 + 6899776 + 7079424 = \mathbf{13462288}$$

Fully Connected Layers

Now let's calculate the parameters for the fully connected layers:

- **Dense Layer with** 4096:

$$(\text{input units} + 1) \times \text{output units} = (25088 + 1) \times 4096 = 102764544$$

- **Dense Layer with** 4096:

$$(4096 + 1) \times 4096 = 16781312$$

- **Dense Layer with** 1000:

$$(4096 + 1) \times 1000 = 4097000$$

Total Fully Connected Layer Parameters

Total for all fully connected layers:

$$102764544 + 16781312 + 4097000 = \mathbf{138357544}$$

Final Calculation of Total Parameters

Now we can sum up both parts to confirm the total number of parameters:

Total parameters from convolutional layers and fully connected layers:

$$13462288 + 138357544 = \mathbf{151819832}$$

Problem-3:

Build a CNN which will look like VGG16, but not similar to VGG16 by fulfilling the following conditions
Conditions:

- Different students should have different input shape and output shape
- Different students should have different number of dense layers and number of neurons in dense layers
- Different student should have different number convolution layers in different block
- Different students should have different pooling layers or down-sampling techniques

Parameter Calculation:

Layer-by-Layer Parameter Calculation

1. Input Layer

- **Input Shape**: `(128, 128, 3)` (This layer does not have parameters.)

2. Convolutional Layers

The formula for calculating the number of parameters in a `Conv2D` layer is:

$$\text{Parameters} = (\text{filter height} \times \text{filter width} \times \text{input channels} + 1) \times \text{number of filte}$$

Where:

- **filter_height** and **filter_width**: Size of the convolutional filter (3x3 in this case).
- **input_channels**: Number of channels in the input (3 for RGB images).
- **number_of_filters**: Number of filters in the convolutional layer.
- The "+1" accounts for the bias term.

Block 1

- **Conv2D (32 filters)**:
  - Parameters = $(3 \times 3 \times 3 + 1) \times 32 = (27 + 1) \times 32 = 28 \times 32 = 896$
- **Conv2D (32 filters)**:
  - Parameters = $(3 \times 3 \times 32 + 1) \times 32 = (288 + 1) \times 32 = 289 \times 32 = 9,248$
- **MaxPooling2D**: No parameters.

Block 2

- **Conv2D (64 filters)**:
  - Parameters = $(3 \times 3 \times 32 + 1) \times 64 = (288 + 1) \times 64 = 289 \times 64 = 18,496$
- **Conv2D (64 filters)**:
  - Parameters = $(3 \times 3 \times 64 + 1) \times 64 = (576 + 1) \times 64 = 577 \times 64 = 36,928$
- **MaxPooling2D**: No parameters.

Block 3

- **Conv2D (128 filters)**:
  - Parameters = $(3 \times 3 \times 64 + 1) \times 128 = (576 + 1) \times 128 = 577 \times 128 = 73,856$
- **Conv2D (128 filters)**:
  - Parameters = $(3 \times 3 \times 128 + 1) \times 128 = (1152 + 1) \times 128 = 1153 \times 128 = 147584$

Block 4

- **Conv2D (256 filters)**:
  - Parameters = $(3 \times 3 \times 128 + 1) \times 256 = (1152 + 1) \times 256 = 1153 \times 256 = 295168$
- **MaxPooling2D**: No parameters.

Summary of Convolutional Layer Parameters

Now let's sum up all the parameters from the convolutional layers:

- Block 1:
  - Conv2D(32): 896
  - Conv2D(32): $9,248$
  - Total for Block 1: $896 + 9,248 = 10,144$
- Block 2:
  - Conv2D(64): $18,496$
  - Conv2D(64): $36,928$
  - Total for Block 2: $18,496 + 36,928 = 55,424$
- Block 3:
  - Conv2D(128): $73,856$
  - Conv2D(128): 147584
  - Total for Block3: $73,856 + 147584 = 221440$
- Block4:
  - Conv2D(256): 295168
  - Total for Block4: 295168

Total Convolutional Layer Parameters

Now we can sum all these blocks together:

$$10,144 + 55,424 + 221440 + 295168 = 582176$$

Flatten Layer

The flatten layer does not have any parameters; it simply reshapes the output from the last convolutional layer into a one-dimensional array.

Dense Layers

The formula for calculating the number of parameters in a `Dense` layer is:

$$\text{Parameters} = (\text{input units} + 1) \times \text{output units}$$

Dense Layer Calculations

- **First Dense Layer with `256` neurons**:
  - Input units from Flatten layer: The input size to this layer will be equal to the output size from the last convolutional layer. Let's calculate that.
  - The output shape after the last pooling layer is calculated as follows:
    - Input size to Conv Layer with `256` filters is `(16 x16 x256)` after two pooling layers.
    - Therefore, input units to Dense Layer will be `16 *16 *256=65536`
  - Parameters = $(65536 + 1) \times 256 = 65537 \times 256 = 16711992$
- **Second Dense Layer with `64` neurons**:
  - Input units are `256`.
  - Parameters = $(256 + 1) \times 64 = 257 \times 64 = 16448$

Output Layer

- **Output Layer with `10` neurons:**
  - Input units are `64`.
  - Parameters = $(64 + 1) \times 10 = 65 \times 10 = 650$

Total Parameter Calculation

Now we can sum up all parameters:

Total Parameters Calculation

$$\text{Total Convolutional Params} + (\text{First Dense Params}) + (\text{Second Dense Params}) -$$

$$582176 + 16711992 + 16448 + 650 = 16909466$$

Summary of Total Parameters

The total number of parameters in this custom CNN architecture is approximately **16,909,466**. This includes all convolutional and dense layers while accounting for their respective weights and biases.

If you have any further questions or need clarification on any specific part of this calculation or architecture design, feel free to ask!