ml4sci-24-task2-2-mobilenet

March 26, 2024

[1]:
```
import torch
import numpy as np
import pandas as pd
import pyarrow.parquet as pq
import matplotlib.pyplot as plt
from sklearn.model_selection import train_test_split
import timm
import torch
import torch.nn as nn
from torch.utils.data import Dataset,DataLoader, random_split
import torch.nn.functional as F
from torchvision import models

import torch.optim as optim
from tqdm import tqdm

from sklearn.metrics import roc_auc_score, confusion_matrix ,roc_curve
import seaborn as sns
```

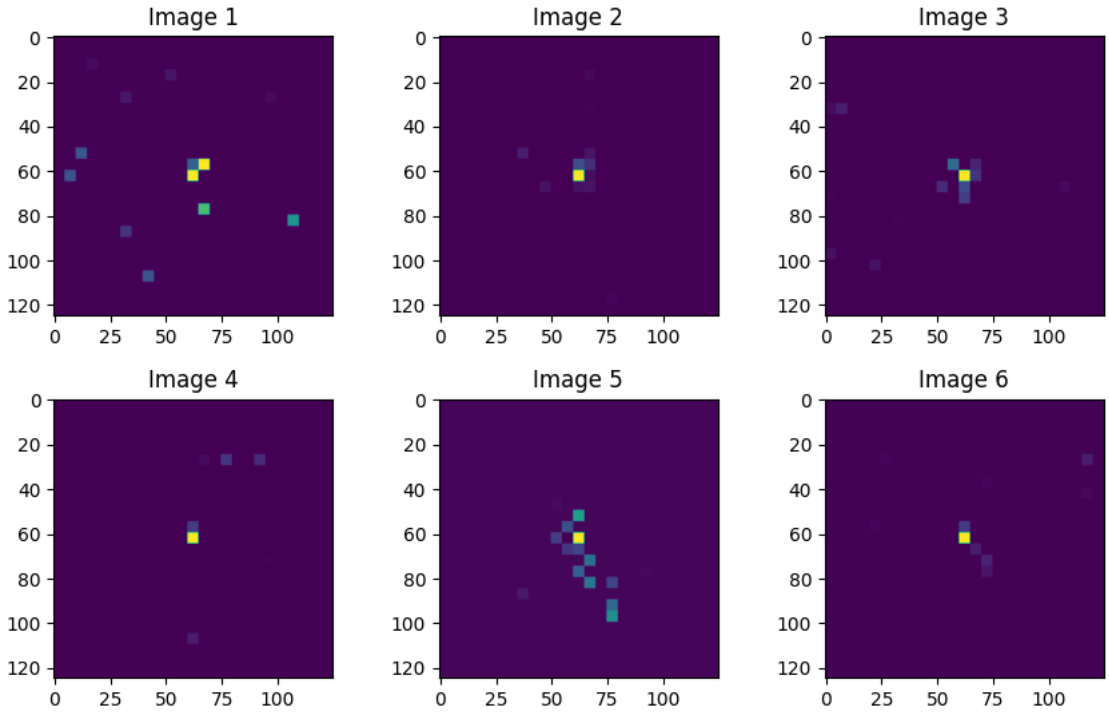
[2]:
```
chunk_size = 5

# List of Parquet file paths
file_paths = [
    '/kaggle/input/task2-24/QCDToGGQQ_IMGjet_RH1all_jet0_run0_n36272.test.
 ↪snappy.parquet',
    '/kaggle/input/task2-24/QCDToGGQQ_IMGjet_RH1all_jet0_run1_n47540.test.
 ↪snappy.parquet',
    '/kaggle/input/task2-24/QCDToGGQQ_IMGjet_RH1all_jet0_run2_n55494.test.
 ↪snappy.parquet'
]

# Initialize an empty list to store dataframes
dfs = []

# Loop through each file path
for file_path in file_paths:
    # Create a Parquet file reader object
```

```
    parquet_file = pq.ParquetFile(file_path)

    # Determine the total number of rows in the file
    total_rows = parquet_file.metadata.num_rows

    # Calculate the number of chunks
    num_chunks = total_rows // chunk_size + (1 if total_rows % chunk_size else␣
 ↪0)

    # Loop over the file in chunks
    for chunk_index in range(num_chunks):
        # Read a chunk of rows from the file
        chunk = parquet_file.read_row_group(chunk_index, columns=None)
        df = chunk.to_pandas()

        # Append the DataFrame to the list
        dfs.append(df)

# Concatenate all the DataFrames into a single DataFrame
data = pd.concat(dfs, ignore_index=True)
```

[3]:
```
def to_3d(arr):
    vishak=[]
    for i in range (0,3):
        vis=np.stack(np.stack(arr)[i],axis=-1)
        vishak.append(vis)
    vishak=np.array(vishak)
    vishak = (vishak - vishak.min())/(vishak.max()- vishak.min())
    return vishak
```

[4]:
```
data["X_jets"]  = data["X_jets"].apply(to_3d)
```

[5]:
```
fig, axes = plt.subplots(nrows=2, ncols=3, figsize=(10, 6))

# Loop over the axes and image ids, and plot each image on a separate subplot
for i, ax in enumerate(axes.flatten()):
    image = data['X_jets'][i][2,:,:]
    ax.imshow(image)
    ax.set_title(f'Image {i+1}')

# Adjust spacing between subplots
plt.subplots_adjust(left=0.1, right=0.9, bottom=0.1, top=0.9, wspace=0.3,␣
 ↪hspace=0.3)

# Show the plot
plt.show()
```



[6]:
```
data.columns
```

[6]:
```
Index(['X_jets', 'pt', 'm0', 'y'], dtype='object')
```

[7]:
```
# data['y']
```

[8]:
```
class task2Dataset(Dataset):
    def __init__(self, dataframe, transform=None):
        self.dataframe = dataframe
        self.transform = transform

    def __len__(self):
        return len(self.dataframe)

    def __getitem__(self, idx):
        # Assuming 'X_jets' column contains paths to images or actual image data
        X = self.dataframe.iloc[idx]['X_jets']
        mean = X.mean(axis=(0, 1, 2), keepdims=True)
        std = X.std(axis=(0, 1, 2), keepdims=True)

        # Normalize each channel separately
        X = (X - mean) / std
        y = self.dataframe.iloc[idx]['y']
```

```
        if self.transform:
            X = self.transform(X)

        # Convert X and y to PyTorch tensors
        X_tensor = torch.tensor(X, dtype=torch.float)
        y_tensor = torch.tensor(y, dtype=torch.long)

        return X_tensor, y_tensor
```

[9]:
```
jet_dataset = task2Dataset(dataframe=data)


train_dataset, val_dataset = train_test_split(jet_dataset, test_size=0.2,␣
 ↪random_state=42)


train_loader = DataLoader(dataset=train_dataset, batch_size=256, shuffle=True)
val_loader = DataLoader(dataset=val_dataset, batch_size=32, shuffle=False)
```

[10]:
```
next(iter(train_loader))[0].shape
```

[10]:
```
torch.Size([256, 3, 125, 125])
```

[11]:
```
class CustomMobileNetV3(nn.Module):
    def __init__(self, num_classes=2, pretrained=True):
        super(CustomMobileNetV3, self).__init__()
        self.model = timm.create_model('mobilenetv3_large_100',␣
 ↪pretrained=pretrained, num_classes=num_classes)

    def forward(self, x):
        return self.model(x)

# Initialize your model
model = CustomMobileNetV3(num_classes=2, pretrained=True)
print(model)
```

```
model.safetensors:   0%|          | 0.00/22.1M [00:00<?, ?B/s]
```

```
CustomMobileNetV3(
  (model): MobileNetV3(
    (conv_stem): Conv2d(3, 16, kernel_size=(3, 3), stride=(2, 2), padding=(1,
1), bias=False)
    (bn1): BatchNormAct2d(
      16, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True
      (drop): Identity()
      (act): Hardswish()
    )
    (blocks): Sequential(
```

```
      (0): Sequential(
        (0): DepthwiseSeparableConv(
          (conv_dw): Conv2d(16, 16, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), groups=16, bias=False)
          (bn1): BatchNormAct2d(
            16, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True
            (drop): Identity()
            (act): ReLU(inplace=True)
          )
          (se): Identity()
          (conv_pw): Conv2d(16, 16, kernel_size=(1, 1), stride=(1, 1),
bias=False)
          (bn2): BatchNormAct2d(
            16, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True
            (drop): Identity()
            (act): Identity()
          )
          (drop_path): Identity()
        )
      )
      (1): Sequential(
        (0): InvertedResidual(
          (conv_pw): Conv2d(16, 64, kernel_size=(1, 1), stride=(1, 1),
bias=False)
          (bn1): BatchNormAct2d(
            64, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True
            (drop): Identity()
            (act): ReLU(inplace=True)
          )
          (conv_dw): Conv2d(64, 64, kernel_size=(3, 3), stride=(2, 2),
padding=(1, 1), groups=64, bias=False)
          (bn2): BatchNormAct2d(
            64, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True
            (drop): Identity()
            (act): ReLU(inplace=True)
          )
          (se): Identity()
          (conv_pwl): Conv2d(64, 24, kernel_size=(1, 1), stride=(1, 1),
bias=False)
          (bn3): BatchNormAct2d(
            24, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True
            (drop): Identity()
            (act): Identity()
          )
          (drop_path): Identity()
        )
        (1): InvertedResidual(
          (conv_pw): Conv2d(24, 72, kernel_size=(1, 1), stride=(1, 1),
```

```
bias=False)
          (bn1): BatchNormAct2d(
            72, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True
            (drop): Identity()
            (act): ReLU(inplace=True)
          )
          (conv_dw): Conv2d(72, 72, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), groups=72, bias=False)
          (bn2): BatchNormAct2d(
            72, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True
            (drop): Identity()
            (act): ReLU(inplace=True)
          )
          (se): Identity()
          (conv_pwl): Conv2d(72, 24, kernel_size=(1, 1), stride=(1, 1),
bias=False)
          (bn3): BatchNormAct2d(
            24, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True
            (drop): Identity()
            (act): Identity()
          )
          (drop_path): Identity()
        )
      )
      (2): Sequential(
        (0): InvertedResidual(
          (conv_pw): Conv2d(24, 72, kernel_size=(1, 1), stride=(1, 1),
bias=False)
          (bn1): BatchNormAct2d(
            72, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True
            (drop): Identity()
            (act): ReLU(inplace=True)
          )
          (conv_dw): Conv2d(72, 72, kernel_size=(5, 5), stride=(2, 2),
padding=(2, 2), groups=72, bias=False)
          (bn2): BatchNormAct2d(
            72, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True
            (drop): Identity()
            (act): ReLU(inplace=True)
          )
          (se): SqueezeExcite(
            (conv_reduce): Conv2d(72, 24, kernel_size=(1, 1), stride=(1, 1))
            (act1): ReLU(inplace=True)
            (conv_expand): Conv2d(24, 72, kernel_size=(1, 1), stride=(1, 1))
            (gate): Hardsigmoid()
          )
          (conv_pwl): Conv2d(72, 40, kernel_size=(1, 1), stride=(1, 1),
bias=False)
```

```
          (bn3): BatchNormAct2d(
            40, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True
            (drop): Identity()
            (act): Identity()
          )
          (drop_path): Identity()
        )
        (1): InvertedResidual(
          (conv_pw): Conv2d(40, 120, kernel_size=(1, 1), stride=(1, 1),
bias=False)
          (bn1): BatchNormAct2d(
            120, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True
            (drop): Identity()
            (act): ReLU(inplace=True)
          )
          (conv_dw): Conv2d(120, 120, kernel_size=(5, 5), stride=(1, 1),
padding=(2, 2), groups=120, bias=False)
          (bn2): BatchNormAct2d(
            120, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True
            (drop): Identity()
            (act): ReLU(inplace=True)
          )
          (se): SqueezeExcite(
            (conv_reduce): Conv2d(120, 32, kernel_size=(1, 1), stride=(1, 1))
            (act1): ReLU(inplace=True)
            (conv_expand): Conv2d(32, 120, kernel_size=(1, 1), stride=(1, 1))
            (gate): Hardsigmoid()
          )
          (conv_pwl): Conv2d(120, 40, kernel_size=(1, 1), stride=(1, 1),
bias=False)
          (bn3): BatchNormAct2d(
            40, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True
            (drop): Identity()
            (act): Identity()
          )
          (drop_path): Identity()
        )
        (2): InvertedResidual(
          (conv_pw): Conv2d(40, 120, kernel_size=(1, 1), stride=(1, 1),
bias=False)
          (bn1): BatchNormAct2d(
            120, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True
            (drop): Identity()
            (act): ReLU(inplace=True)
          )
          (conv_dw): Conv2d(120, 120, kernel_size=(5, 5), stride=(1, 1),
padding=(2, 2), groups=120, bias=False)
          (bn2): BatchNormAct2d(
```

```
            120, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True
            (drop): Identity()
            (act): ReLU(inplace=True)
          )
          (se): SqueezeExcite(
            (conv_reduce): Conv2d(120, 32, kernel_size=(1, 1), stride=(1, 1))
            (act1): ReLU(inplace=True)
            (conv_expand): Conv2d(32, 120, kernel_size=(1, 1), stride=(1, 1))
            (gate): Hardsigmoid()
          )
          (conv_pwl): Conv2d(120, 40, kernel_size=(1, 1), stride=(1, 1),
bias=False)
          (bn3): BatchNormAct2d(
            40, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True
            (drop): Identity()
            (act): Identity()
          )
          (drop_path): Identity()
        )
      )
      (3): Sequential(
        (0): InvertedResidual(
          (conv_pw): Conv2d(40, 240, kernel_size=(1, 1), stride=(1, 1),
bias=False)
          (bn1): BatchNormAct2d(
            240, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True
            (drop): Identity()
            (act): Hardswish()
          )
          (conv_dw): Conv2d(240, 240, kernel_size=(3, 3), stride=(2, 2),
padding=(1, 1), groups=240, bias=False)
          (bn2): BatchNormAct2d(
            240, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True
            (drop): Identity()
            (act): Hardswish()
          )
          (se): Identity()
          (conv_pwl): Conv2d(240, 80, kernel_size=(1, 1), stride=(1, 1),
bias=False)
          (bn3): BatchNormAct2d(
            80, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True
            (drop): Identity()
            (act): Identity()
          )
          (drop_path): Identity()
        )
        (1): InvertedResidual(
          (conv_pw): Conv2d(80, 200, kernel_size=(1, 1), stride=(1, 1),
```

```
bias=False)
          (bn1): BatchNormAct2d(
            200, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True
            (drop): Identity()
            (act): Hardswish()
          )
          (conv_dw): Conv2d(200, 200, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), groups=200, bias=False)
          (bn2): BatchNormAct2d(
            200, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True
            (drop): Identity()
            (act): Hardswish()
          )
          (se): Identity()
          (conv_pwl): Conv2d(200, 80, kernel_size=(1, 1), stride=(1, 1),
bias=False)
          (bn3): BatchNormAct2d(
            80, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True
            (drop): Identity()
            (act): Identity()
          )
          (drop_path): Identity()
        )
        (2): InvertedResidual(
          (conv_pw): Conv2d(80, 184, kernel_size=(1, 1), stride=(1, 1),
bias=False)
          (bn1): BatchNormAct2d(
            184, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True
            (drop): Identity()
            (act): Hardswish()
          )
          (conv_dw): Conv2d(184, 184, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), groups=184, bias=False)
          (bn2): BatchNormAct2d(
            184, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True
            (drop): Identity()
            (act): Hardswish()
          )
          (se): Identity()
          (conv_pwl): Conv2d(184, 80, kernel_size=(1, 1), stride=(1, 1),
bias=False)
          (bn3): BatchNormAct2d(
            80, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True
            (drop): Identity()
            (act): Identity()
          )
          (drop_path): Identity()
        )
```

```
        (3): InvertedResidual(
          (conv_pw): Conv2d(80, 184, kernel_size=(1, 1), stride=(1, 1),
bias=False)
          (bn1): BatchNormAct2d(
            184, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True
            (drop): Identity()
            (act): Hardswish()
          )
          (conv_dw): Conv2d(184, 184, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), groups=184, bias=False)
          (bn2): BatchNormAct2d(
            184, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True
            (drop): Identity()
            (act): Hardswish()
          )
          (se): Identity()
          (conv_pwl): Conv2d(184, 80, kernel_size=(1, 1), stride=(1, 1),
bias=False)
          (bn3): BatchNormAct2d(
            80, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True
            (drop): Identity()
            (act): Identity()
          )
          (drop_path): Identity()
        )
      )
      (4): Sequential(
        (0): InvertedResidual(
          (conv_pw): Conv2d(80, 480, kernel_size=(1, 1), stride=(1, 1),
bias=False)
          (bn1): BatchNormAct2d(
            480, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True
            (drop): Identity()
            (act): Hardswish()
          )
          (conv_dw): Conv2d(480, 480, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), groups=480, bias=False)
          (bn2): BatchNormAct2d(
            480, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True
            (drop): Identity()
            (act): Hardswish()
          )
          (se): SqueezeExcite(
            (conv_reduce): Conv2d(480, 120, kernel_size=(1, 1), stride=(1, 1))
            (act1): ReLU(inplace=True)
            (conv_expand): Conv2d(120, 480, kernel_size=(1, 1), stride=(1, 1))
            (gate): Hardsigmoid()
          )
```

```
          (conv_pwl): Conv2d(480, 112, kernel_size=(1, 1), stride=(1, 1),
bias=False)
          (bn3): BatchNormAct2d(
            112, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True
            (drop): Identity()
            (act): Identity()
          )
          (drop_path): Identity()
        )
        (1): InvertedResidual(
          (conv_pw): Conv2d(112, 672, kernel_size=(1, 1), stride=(1, 1),
bias=False)
          (bn1): BatchNormAct2d(
            672, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True
            (drop): Identity()
            (act): Hardswish()
          )
          (conv_dw): Conv2d(672, 672, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), groups=672, bias=False)
          (bn2): BatchNormAct2d(
            672, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True
            (drop): Identity()
            (act): Hardswish()
          )
          (se): SqueezeExcite(
            (conv_reduce): Conv2d(672, 168, kernel_size=(1, 1), stride=(1, 1))
            (act1): ReLU(inplace=True)
            (conv_expand): Conv2d(168, 672, kernel_size=(1, 1), stride=(1, 1))
            (gate): Hardsigmoid()
          )
          (conv_pwl): Conv2d(672, 112, kernel_size=(1, 1), stride=(1, 1),
bias=False)
          (bn3): BatchNormAct2d(
            112, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True
            (drop): Identity()
            (act): Identity()
          )
          (drop_path): Identity()
        )
      )
      (5): Sequential(
        (0): InvertedResidual(
          (conv_pw): Conv2d(112, 672, kernel_size=(1, 1), stride=(1, 1),
bias=False)
          (bn1): BatchNormAct2d(
            672, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True
            (drop): Identity()
            (act): Hardswish()
```

```
          )
          (conv_dw): Conv2d(672, 672, kernel_size=(5, 5), stride=(2, 2),
padding=(2, 2), groups=672, bias=False)
          (bn2): BatchNormAct2d(
            672, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True
            (drop): Identity()
            (act): Hardswish()
          )
          (se): SqueezeExcite(
            (conv_reduce): Conv2d(672, 168, kernel_size=(1, 1), stride=(1, 1))
            (act1): ReLU(inplace=True)
            (conv_expand): Conv2d(168, 672, kernel_size=(1, 1), stride=(1, 1))
            (gate): Hardsigmoid()
          )
          (conv_pwl): Conv2d(672, 160, kernel_size=(1, 1), stride=(1, 1),
bias=False)
          (bn3): BatchNormAct2d(
            160, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True
            (drop): Identity()
            (act): Identity()
          )
          (drop_path): Identity()
        )
        (1): InvertedResidual(
          (conv_pw): Conv2d(160, 960, kernel_size=(1, 1), stride=(1, 1),
bias=False)
          (bn1): BatchNormAct2d(
            960, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True
            (drop): Identity()
            (act): Hardswish()
          )
          (conv_dw): Conv2d(960, 960, kernel_size=(5, 5), stride=(1, 1),
padding=(2, 2), groups=960, bias=False)
          (bn2): BatchNormAct2d(
            960, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True
            (drop): Identity()
            (act): Hardswish()
          )
          (se): SqueezeExcite(
            (conv_reduce): Conv2d(960, 240, kernel_size=(1, 1), stride=(1, 1))
            (act1): ReLU(inplace=True)
            (conv_expand): Conv2d(240, 960, kernel_size=(1, 1), stride=(1, 1))
            (gate): Hardsigmoid()
          )
          (conv_pwl): Conv2d(960, 160, kernel_size=(1, 1), stride=(1, 1),
bias=False)
          (bn3): BatchNormAct2d(
            160, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True
```

```
            (drop): Identity()
            (act): Identity()
          )
          (drop_path): Identity()
        )
        (2): InvertedResidual(
          (conv_pw): Conv2d(160, 960, kernel_size=(1, 1), stride=(1, 1),
bias=False)
          (bn1): BatchNormAct2d(
            960, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True
            (drop): Identity()
            (act): Hardswish()
          )
          (conv_dw): Conv2d(960, 960, kernel_size=(5, 5), stride=(1, 1),
padding=(2, 2), groups=960, bias=False)
          (bn2): BatchNormAct2d(
            960, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True
            (drop): Identity()
            (act): Hardswish()
          )
          (se): SqueezeExcite(
            (conv_reduce): Conv2d(960, 240, kernel_size=(1, 1), stride=(1, 1))
            (act1): ReLU(inplace=True)
            (conv_expand): Conv2d(240, 960, kernel_size=(1, 1), stride=(1, 1))
            (gate): Hardsigmoid()
          )
          (conv_pwl): Conv2d(960, 160, kernel_size=(1, 1), stride=(1, 1),
bias=False)
          (bn3): BatchNormAct2d(
            160, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True
            (drop): Identity()
            (act): Identity()
          )
          (drop_path): Identity()
        )
      )
      (6): Sequential(
        (0): ConvBnAct(
          (conv): Conv2d(160, 960, kernel_size=(1, 1), stride=(1, 1),
bias=False)
          (bn1): BatchNormAct2d(
            960, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True
            (drop): Identity()
            (act): Hardswish()
          )
          (drop_path): Identity()
        )
      )
```

```
    )
    (global_pool): SelectAdaptivePool2d(pool_type=avg, flatten=Identity())
    (conv_head): Conv2d(960, 1280, kernel_size=(1, 1), stride=(1, 1))
    (act2): Hardswish()
    (flatten): Flatten(start_dim=1, end_dim=-1)
    (classifier): Linear(in_features=1280, out_features=2, bias=True)
  )
)
```

[12]:
```
device = torch.device("cuda" if torch.cuda.is_available() else "cpu")


model.to(device)

criterion = nn.CrossEntropyLoss()
optimizer = optim.Adam(model.parameters(), lr=0.0001)
scheduler = optim.lr_scheduler.StepLR(optimizer, step_size=30, gamma=0.1)
```

[13]:
```
num_epochs = 20
train_losses, val_losses, val_accuracies = [], [], []
best_loss = 100000
for epoch in range(num_epochs):
    model.train()
    running_loss = 0.0
    train_bar = tqdm(train_loader, desc=f"Epoch {epoch+1}/{num_epochs} [Train]␣
 ↪Loss: 0.0000", leave=False)
    for inputs, labels in train_bar:
        inputs, labels = inputs.to(device), labels.to(device)

        optimizer.zero_grad()

        outputs = model(inputs)
        loss = criterion(outputs, labels)
        loss.backward()
        optimizer.step()

        running_loss += loss.item() * inputs.size(0)
        train_bar.set_description(f"Epoch {epoch+1}/{num_epochs} [Train] Loss:␣
 ↪{loss.item():.4f}")

    #scheduler.step()

    epoch_loss = running_loss / len(train_loader.dataset)
    train_losses.append(epoch_loss)

    # Validation phase
    model.eval()
```

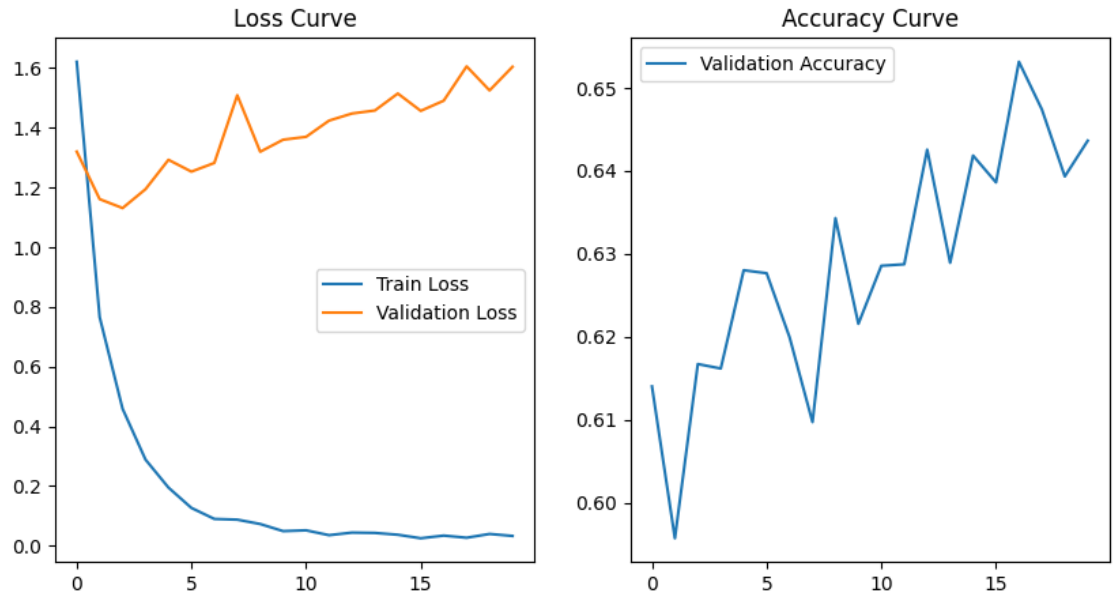
```
    val_running_loss = 0.0
    correct_predictions = 0
    total_predictions = 0
    val_bar = tqdm(val_loader, desc=f"Epoch {epoch+1}/{num_epochs} [Val] Loss:␣
↪0.0000, Acc: 0.0000", leave=True)

    with torch.no_grad():
        for inputs, labels in val_bar:
            inputs, labels = inputs.to(device), labels.to(device)

            outputs = model(inputs)
            loss = criterion(outputs, labels)
            val_running_loss += loss.item() * inputs.size(0)

            _, predicted = torch.max(outputs, 1)
            correct_predictions += (predicted == labels).sum().item()
            total_predictions += labels.size(0)


            val_bar.set_description(f"Epoch {epoch+1}/{num_epochs} [Val] Loss:␣
↪{loss.item():.4f}, Acc: {correct_predictions/total_predictions:.4f}")

    epoch_val_loss = val_running_loss / len(val_loader.dataset)
    val_losses.append(epoch_val_loss)

    epoch_val_accuracy = correct_predictions / total_predictions
    best_loss = min(epoch_val_loss , best_loss)
    val_accuracies.append(epoch_val_accuracy)

    if(epoch_val_loss== best_loss):

            model_path = f"model_weights_{epoch}.pth"
            torch.save(model.state_dict(), model_path)

    print(f"Epoch {epoch+1}/{num_epochs}, Train Loss: {epoch_loss:.4f}, Val␣
↪Loss: {epoch_val_loss:.4f}, Val Accuracy: {epoch_val_accuracy:.4f}")
```

```
Epoch 1/20 [Val] Loss: 1.3562, Acc: 0.6140: 100%|      | 175/175
[00:02<00:00, 77.07it/s]

Epoch 1/20, Train Loss: 1.6215, Val Loss: 1.3205, Val Accuracy: 0.6140

Epoch 2/20 [Val] Loss: 2.2744, Acc: 0.5957: 100%|      | 175/175
[00:02<00:00, 86.00it/s]

Epoch 2/20, Train Loss: 0.7658, Val Loss: 1.1611, Val Accuracy: 0.5957

Epoch 3/20 [Val] Loss: 1.0439, Acc: 0.6167: 100%|      | 175/175
[00:02<00:00, 85.13it/s]
```

```
Epoch 3/20, Train Loss: 0.4585, Val Loss: 1.1312, Val Accuracy: 0.6167

Epoch 4/20 [Val] Loss: 1.1395, Acc: 0.6162: 100%|      | 175/175
[00:02<00:00, 85.85it/s]

Epoch 4/20, Train Loss: 0.2882, Val Loss: 1.1945, Val Accuracy: 0.6162

Epoch 5/20 [Val] Loss: 0.9942, Acc: 0.6280: 100%|      | 175/175
[00:02<00:00, 79.54it/s]

Epoch 5/20, Train Loss: 0.1945, Val Loss: 1.2929, Val Accuracy: 0.6280

Epoch 6/20 [Val] Loss: 1.6614, Acc: 0.6277: 100%|      | 175/175
[00:02<00:00, 81.46it/s]

Epoch 6/20, Train Loss: 0.1264, Val Loss: 1.2533, Val Accuracy: 0.6277

Epoch 7/20 [Val] Loss: 1.2670, Acc: 0.6200: 100%|      | 175/175
[00:02<00:00, 84.18it/s]

Epoch 7/20, Train Loss: 0.0895, Val Loss: 1.2824, Val Accuracy: 0.6200

Epoch 8/20 [Val] Loss: 2.1079, Acc: 0.6097: 100%|      | 175/175
[00:02<00:00, 83.59it/s]

Epoch 8/20, Train Loss: 0.0871, Val Loss: 1.5093, Val Accuracy: 0.6097

Epoch 9/20 [Val] Loss: 1.0984, Acc: 0.6343: 100%|      | 175/175
[00:02<00:00, 81.01it/s]

Epoch 9/20, Train Loss: 0.0725, Val Loss: 1.3199, Val Accuracy: 0.6343

Epoch 10/20 [Val] Loss: 1.4849, Acc: 0.6216: 100%|      | 175/175
[00:02<00:00, 86.05it/s]

Epoch 10/20, Train Loss: 0.0487, Val Loss: 1.3603, Val Accuracy: 0.6216

Epoch 11/20 [Val] Loss: 0.9186, Acc: 0.6286: 100%|      | 175/175
[00:02<00:00, 77.76it/s]

Epoch 11/20, Train Loss: 0.0513, Val Loss: 1.3699, Val Accuracy: 0.6286

Epoch 12/20 [Val] Loss: 1.5534, Acc: 0.6287: 100%|      | 175/175
[00:02<00:00, 80.76it/s]

Epoch 12/20, Train Loss: 0.0351, Val Loss: 1.4242, Val Accuracy: 0.6287

Epoch 13/20 [Val] Loss: 1.0609, Acc: 0.6426: 100%|      | 175/175
[00:02<00:00, 82.66it/s]

Epoch 13/20, Train Loss: 0.0437, Val Loss: 1.4481, Val Accuracy: 0.6426

Epoch 14/20 [Val] Loss: 0.7483, Acc: 0.6289: 100%|      | 175/175
[00:02<00:00, 87.00it/s]

Epoch 14/20, Train Loss: 0.0426, Val Loss: 1.4582, Val Accuracy: 0.6289

Epoch 15/20 [Val] Loss: 1.6908, Acc: 0.6418: 100%|      | 175/175
[00:02<00:00, 75.40it/s]
```

```
Epoch 15/20, Train Loss: 0.0365, Val Loss: 1.5151, Val Accuracy: 0.6418

Epoch 16/20 [Val] Loss: 1.1506, Acc: 0.6386: 100%|      | 175/175
[00:02<00:00, 84.99it/s]

Epoch 16/20, Train Loss: 0.0247, Val Loss: 1.4569, Val Accuracy: 0.6386

Epoch 17/20 [Val] Loss: 0.6856, Acc: 0.6531: 100%|      | 175/175
[00:02<00:00, 83.34it/s]

Epoch 17/20, Train Loss: 0.0337, Val Loss: 1.4910, Val Accuracy: 0.6531

Epoch 18/20 [Val] Loss: 0.7186, Acc: 0.6474: 100%|      | 175/175
[00:02<00:00, 82.40it/s]

Epoch 18/20, Train Loss: 0.0265, Val Loss: 1.6061, Val Accuracy: 0.6474

Epoch 19/20 [Val] Loss: 1.9122, Acc: 0.6393: 100%|      | 175/175
[00:02<00:00, 85.85it/s]

Epoch 19/20, Train Loss: 0.0391, Val Loss: 1.5254, Val Accuracy: 0.6393

Epoch 20/20 [Val] Loss: 1.8346, Acc: 0.6436: 100%|      | 175/175
[00:02<00:00, 80.00it/s]

Epoch 20/20, Train Loss: 0.0325, Val Loss: 1.6046, Val Accuracy: 0.6436
```

[14]:
```python
plt.figure(figsize=(10, 5))
plt.subplot(1, 2, 1)
plt.plot(train_losses, label='Train Loss')
plt.plot(val_losses, label='Validation Loss')
plt.legend()
plt.title('Loss Curve')

plt.subplot(1, 2, 2)
plt.plot(val_accuracies, label='Validation Accuracy')
plt.legend()
plt.title('Accuracy Curve')
plt.show()
```


Loss Curve
Train Loss
Validation Loss
Accuracy Curve
Validation Accuracy

[ ]:

[ ]: