In [1]:

```
import torch
from torch.utils.data import Dataset
import torchvision.transforms as transforms
import os
from PIL import Image
from torch.utils.data import DataLoader
import matplotlib.pyplot as plt
import numpy as np
import torch.nn as nn
import torch.optim as optim
from torch.optim import lr_scheduler
import time
import glob
import yaml
import torchvision
```

In [2]:

```
def set_seed(seed):
    torch.manual_seed(seed)
    np.random.seed(seed)

    # for cuda
    torch.cuda.manual_seed_all(seed)
    torch.backends.cudnn.deterministic = True
```

In [3]:

```
set_seed(0)
```

In [4]:

```
def extract_files():
    import google.colab
    import zipfile

    google.colab.drive.mount('/content/drive')
    PROJECT_DIR = "/content/drive/MyDrive/thesis/data/"

    zip_ref = zipfile.ZipFile(PROJECT_DIR + "fiveK.zip", 'r')
    zip_ref.extractall(".")
    zip_ref.close()
```

In [5]:

```
if 'google.colab' in str(get_ipython()):
  extract_files()
  config_path = "/content/drive/MyDrive/thesis/config.yaml"
else:
  config_path = "../../config.yaml"
```

```
Mounted at /content/drive
```

In [6]:

```
device = torch.device('cuda:0' if torch.cuda.is_available() else 'cpu')
print(device)
```

```
cuda:0
```

In [7]:

```
# List of class directories
class_directories = ['expA', 'expB', 'expC', 'expD', 'expE']
# raw data directory
raw_dir = "raw"
```

In [8]:

```
class CustomDataset(Dataset):
    def __init__(self, data_dir, raw_data_dir, filename, transform=None):
        super().__init__()
        self.filename = filename
        self.transform = transform

        self.classname = self._extract_class_name(data_dir)
        self.encode = {k: i for i, k in enumerate(class_directories)}


        # Read the train.txt file and store the image paths
        with open(self.filename) as f:
            img_paths= []
            raw_img_paths = []
            for line in f:
                line = line.strip()
                img_paths.append(os.path.join(data_dir, line))
                raw_img_paths.append(os.path.join(raw_data_dir, line))

            self.image_paths = img_paths
            self.raw_image_paths = raw_img_paths

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

    def __getitem__(self, index):
```

```
        image_path = self.image_paths[index]
        raw_image_path = self.raw_image_paths[index]
        image = Image.open(image_path)
        raw_image = Image.open(raw_image_path)
        image = np.dstack((np.array(image), np.array(raw_image)))
        label = self.encode[self.classname]
        if self.transform is not None:
            image = self.transform(image)
        return image, label

    def _extract_class_name(self, root_dir):
        # Extract the class name from the root directory
        class_name = os.path.basename(root_dir)
        return class_name
```

In [9]:

```
try:
    # Load configuration
    with open(config_path, 'r') as config_file:
        config = yaml.safe_load(config_file)
except:
    raise FileNotFoundError(f"Config file not found at path: {config_path}")
```

In [10]:

```
try:
    # Load configuration
    with open(config_path, 'r') as config_file:
        config = yaml.safe_load(config_file)
except:
    raise FileNotFoundError(f"Config file not found at path: {config_path}")
```

In [11]:

```
data_folder = config['paths']['data']
train_file = config['paths']['train']
test_file = config['paths']['test']
```

In [12]:

```
def read_dataset(data_folder, txt_file, trasform=None):
    # Create separate datasets for each class
    datasets = []

    for class_dir in class_directories:
        class_train_dataset = CustomDataset(
            data_dir=os.path.join(data_folder, class_dir),
            raw_data_dir=os.path.join(data_folder, raw_dir),
```

```
            filename=os.path.join(txt_file),
            transform=trasform
        )
        datasets.append(class_train_dataset)
    return datasets
```

In [13]:

```
training_tr = transforms.Compose([
        transforms.ToTensor(),
        transforms.RandomResizedCrop(224, antialias=True),
        transforms.RandomHorizontalFlip(),
        transforms.Normalize([0.485, 0.456, 0.406, 0.485, 0.456, 0.406], [0.229, 0.224, 0.225, 0.229, 0.224, 0.225])
    ])

test_tr = transforms.Compose([
        transforms.ToTensor(),
        transforms.CenterCrop(224),
        transforms.Normalize([0.485, 0.456, 0.406, 0.485, 0.456, 0.406], [0.229, 0.224, 0.225, 0.229, 0.224, 0.225])
    ])
```

In [14]:

```
# Combine datasets if needed (e.g., for training)
train_dataset = torch.utils.data.ConcatDataset(read_dataset(data_folder, train_file, training_tr))
test_dataset = torch.utils.data.ConcatDataset(read_dataset(data_folder, test_file, test_tr))
```

In [15]:

```
bs = 128
```

In [16]:

```
train_dataloader = DataLoader(train_dataset, batch_size=bs, shuffle=True)
test_dataloader = DataLoader(test_dataset, batch_size=bs*2, shuffle=False)
```

In [17]:

```
train_features, train_labels = next(iter(train_dataloader))
```

In [18]:

```
train_features.size()
```

Out[18]:

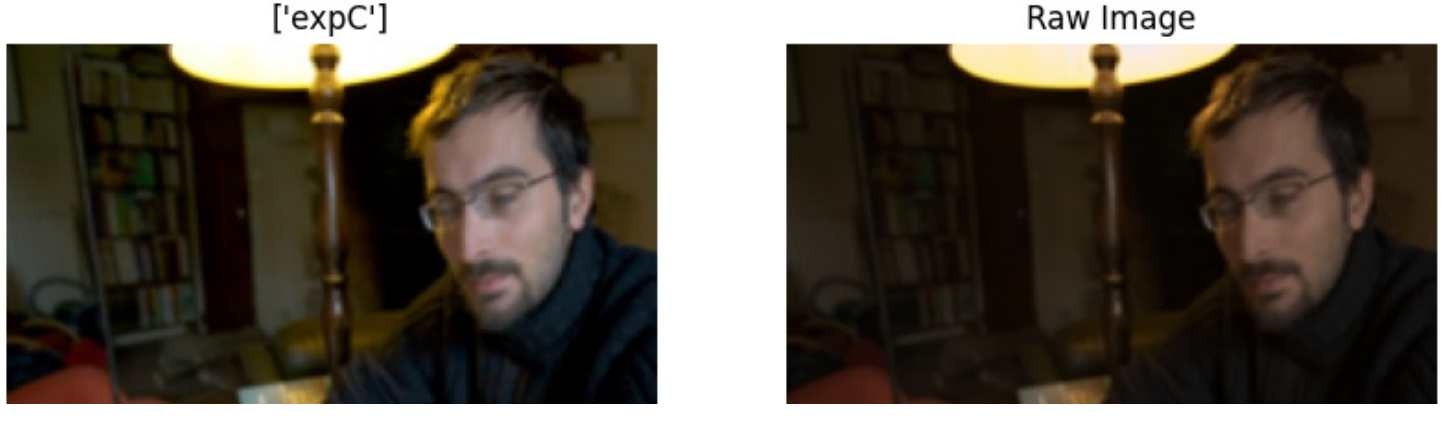
```
torch.Size([128, 6, 224, 224])
```

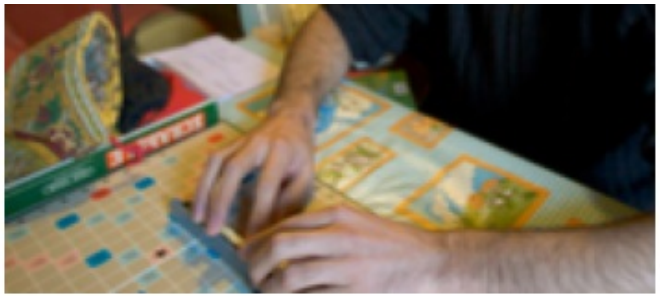
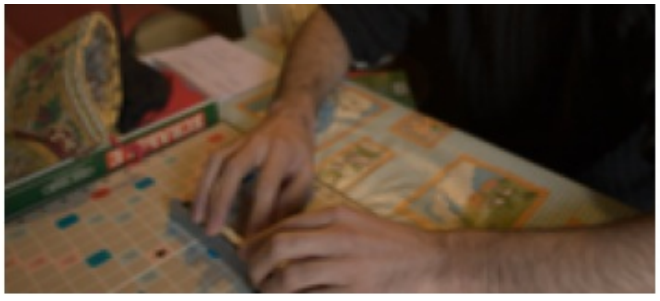
In [19]:

```
def imshow(inp, title=None):
    """Display image for Tensor."""
    inp = inp.numpy().transpose((1, 2, 0))
    org_img = inp[:, :, :3]
    raw_img = inp[:, :, 3:]
    mean = np.array([0.485, 0.456, 0.406])
    std = np.array([0.229, 0.224, 0.225])
    org_img = std * org_img + mean
    raw_img = std * raw_img + mean
    org_img = np.clip(org_img, 0, 1)
    raw_img = np.clip(raw_img, 0, 1)

    # Create a figure with two subplots
    fig, axes = plt.subplots(1, 2, figsize=(10, 5))

    # Plot original image on the first subplot
    axes[0].imshow(org_img)
    if title is not None:
        axes[0].set_title(title)
    axes[0].axis('off')

    # Plot raw image on the second subplot
    axes[1].imshow(raw_img)
    axes[1].set_title('Raw Image')
    axes[1].axis('off')

    plt.pause(0.001)  # pause a bit so that plots are updated
    plt.show()
```

In [20]:

```
# Get a batch of training data
inputs, labels = next(iter(train_dataloader))
out = inputs[:1].squeeze()

imshow(out, title=[class_directories[x] for x in labels[:1]])
```



In [21]:

```
print(len(train_dataset))
```

```
20000
```

In [22]:

```
base_checkpoint_path = config['paths']['checkpoints']
# Create the directory if it does not exist
if not os.path.exists(base_checkpoint_path):
    os.makedirs(base_checkpoint_path)
```

In [23]:

```
def get_lr(optimizer):
    for param_group in optimizer.param_groups:
        return param_group['lr']
```

In [24]:

```
def train_model(model, criterion, optimizer, scheduler, current_epoch, num_epochs=25):
    since = time.time()
    best_acc = 0.0
    model.train()
    for epoch in range(current_epoch, num_epochs):
            # formatted string to append epoch number to checkpoint filename
        print(f'Epoch {epoch + 1}/{num_epochs}')
        print('-' * 10)
        running_loss = 0.0
        running_corrects = 0
        # Iterate over data.
        for inputs, labels in train_dataloader:
            inputs = inputs.to(device)
            labels = labels.to(device)

            # zero the parameter gradients
            optimizer.zero_grad()
            outputs = model(inputs)
```

```
            _, preds = torch.max(outputs, 1)
            loss = criterion(outputs, labels)
            loss.backward()
            optimizer.step()

            # statistics
            running_loss += loss.item() * inputs.size(0)
            running_corrects += torch.sum(preds == labels.data)

        scheduler.step()

        epoch_loss = running_loss / len(train_dataset)
        epoch_acc = running_corrects.double() / len(train_dataset)

        print(f'Loss: {epoch_loss:.4f} Acc: {epoch_acc:.4f} LR: {get_lr(optimizer):.8f}')
        print()

        PATH = os.path.join(base_checkpoint_path, f'{os.path.basename(base_checkpoint_path)}_{epoch+1}.pth')
        # save checkpoint
        state = {
            'epoch': epoch + 1,
            'state_dict': model.state_dict(),
            'optimizer': optimizer.state_dict(),
            'loss': epoch_loss,
            'scheduler': scheduler.state_dict(),
            'accuracy': epoch_acc
        }
        # save the best model parameters
        torch.save(state, PATH)
        # deep copy the model
        if epoch_acc > best_acc:
            best_acc = epoch_acc

    time_elapsed = time.time() - since
    print(f'Training complete in {time_elapsed // 60:.0f}m {time_elapsed % 60:.0f}s')
    print(f'Best Acc: {best_acc:4f}')
```

In [25]:

```
model_name = config['model']['name']
if not model_name.startswith('resnet'):
    raise ValueError("Model name must start with 'resnet'")
```

In [26]:

```
if config['model']['type'] == 'FEATURE_EXTRACTOR':
    model = torchvision.models.__dict__[model_name](weights='IMAGENET1K_V1')
    # Freeze all layers except the fully connected layers
    for param in model.parameters():
        param.requires_grad = False
```

```
elif config['model']['type'] == 'FINE_TUNING':
    model = torchvision.models.__dict__[model_name](weights='IMAGENET1K_V1')
elif config['model']['type'] == 'TRAIN_FROM_SCRATCH':
    model = torchvision.models.__dict__[model_name](weights=None)
else:
    raise ValueError(f"Unknown model type: {config['model']['type']}")

# Parameters of newly constructed modules have requires_grad=True by default
num_ftrs = model.fc.in_features
model.fc =  nn.Linear(num_ftrs, config['model']['num_classes'])

# change the first convolution to accept 6 channels
model.conv1 = nn.Conv2d(6, 64, kernel_size=(7, 7), stride=(2, 2), padding=(3, 3), bias=False)

# move the model to GPU/CPU
model = model.to(device)

criterion = nn.CrossEntropyLoss()

optimizer = optim.SGD(model.parameters(), lr=config['model']['lr'], momentum=config['model']['momentum'])

milestones = [9, 18, 34, 50, 70]

# Decay LR by a factor of 0.1 every 7 epochs
scheduler = lr_scheduler.MultiStepLR(optimizer, milestones, gamma=0.1)
```

In [27]:

```
# load the last model saved if there is any
def load_latest_model(model, optimizer, scheduler, checkpoint_dir):
    # Check if the directory exists
    if not os.path.exists(base_checkpoint_path):
        print(f"No directory found: {checkpoint_dir}")
        return model, optimizer, scheduler, 0, None

    # Get a list of all checkpoint files in the directory
    checkpoint_files = glob.glob(os.path.join(checkpoint_dir, f'{os.path.basename(checkpoint_dir)}_*.pth'))
    print(checkpoint_files)
    # Check if any checkpoint files are present
    if not checkpoint_files:
        print(f"No checkpoints found in the directory: {checkpoint_dir}")
        return model, optimizer, scheduler, 0, None

    # Find the latest checkpoint file based on the epoch number in the filename
    latest_checkpoint = max(checkpoint_files, key=os.path.getctime)

    # Load the latest checkpoint
    checkpoint = torch.load(latest_checkpoint, map_location=torch.device(device))
    model.load_state_dict(checkpoint['state_dict'])
    optimizer.load_state_dict(checkpoint['optimizer'])
```

```
    scheduler.load_state_dict(checkpoint['scheduler'])
    epoch = checkpoint['epoch']
    loss = checkpoint['loss']
    print(checkpoint['accuracy'])

    print(f"Loaded model from checkpoint: {latest_checkpoint}")
    print(f"Resuming training from epoch {epoch}")

    return model, optimizer,scheduler, epoch, loss
```

In [28]:

```
model, optimizer, scheduler, current_epoch, loss = load_latest_model(model, optimizer, scheduler, base_checkpoint_path)
```

```
[]
No checkpoints found in the directory: /content/drive/MyDrive/thesis/model/checkpoints/resetnet50_scratch_raw
```

In [29]:

```
print(get_lr(optimizer))
```

```
0.01
```

In [30]:

```
train_model(model, criterion, optimizer, scheduler,current_epoch, num_epochs=config['model']['num_epochs'])
```

```
Epoch 1/80
----------
Loss: 1.8919 Acc: 0.2657 LR: 0.01000000

Epoch 2/80
----------
Loss: 1.5031 Acc: 0.3679 LR: 0.01000000

Epoch 3/80
----------
Loss: 1.4509 Acc: 0.3945 LR: 0.01000000

Epoch 4/80
----------
Loss: 1.3949 Acc: 0.4219 LR: 0.01000000

Epoch 5/80
----------
Loss: 1.3628 Acc: 0.4372 LR: 0.01000000

Epoch 6/80
----------
Loss: 1.3333 Acc: 0.4529 LR: 0.01000000
```

```
Epoch 7/80
----------
Loss: 1.3111 Acc: 0.4652 LR: 0.01000000

Epoch 8/80
----------
Loss: 1.2853 Acc: 0.4760 LR: 0.01000000

Epoch 9/80
----------
Loss: 1.2677 Acc: 0.4873 LR: 0.00100000

Epoch 10/80
----------
Loss: 1.1954 Acc: 0.5176 LR: 0.00100000

Epoch 11/80
----------
Loss: 1.1725 Acc: 0.5273 LR: 0.00100000

Epoch 12/80
----------
Loss: 1.1624 Acc: 0.5331 LR: 0.00100000

Epoch 13/80
----------
Loss: 1.1516 Acc: 0.5361 LR: 0.00100000

Epoch 14/80
----------
Loss: 1.1457 Acc: 0.5417 LR: 0.00100000

Epoch 15/80
----------
Loss: 1.1413 Acc: 0.5433 LR: 0.00100000

Epoch 16/80
----------
Loss: 1.1359 Acc: 0.5439 LR: 0.00100000

Epoch 17/80
----------
Loss: 1.1301 Acc: 0.5455 LR: 0.00100000

Epoch 18/80
----------
Loss: 1.1243 Acc: 0.5518 LR: 0.00010000

Epoch 19/80
----------
```

```
Loss: 1.1099 Acc: 0.5594 LR: 0.00010000

Epoch 20/80
----------
Loss: 1.1020 Acc: 0.5570 LR: 0.00010000

Epoch 21/80
----------
Loss: 1.1029 Acc: 0.5610 LR: 0.00010000

Epoch 22/80
----------
Loss: 1.1024 Acc: 0.5572 LR: 0.00010000

Epoch 23/80
----------
Loss: 1.0979 Acc: 0.5631 LR: 0.00010000

Epoch 24/80
----------
Loss: 1.1001 Acc: 0.5621 LR: 0.00010000

Epoch 25/80
----------
Loss: 1.0958 Acc: 0.5620 LR: 0.00010000

Epoch 26/80
----------
Loss: 1.0985 Acc: 0.5590 LR: 0.00010000

Epoch 27/80
----------
Loss: 1.0966 Acc: 0.5630 LR: 0.00010000

Epoch 28/80
----------
Loss: 1.0965 Acc: 0.5662 LR: 0.00010000

Epoch 29/80
----------
Loss: 1.0933 Acc: 0.5629 LR: 0.00010000

Epoch 30/80
----------
Loss: 1.0945 Acc: 0.5630 LR: 0.00010000

Epoch 31/80
----------
Loss: 1.0947 Acc: 0.5639 LR: 0.00010000

Epoch 32/80
```

Epoch 32/80

Loss: 1.0936 Acc: 0.5646 LR: 0.00010000

Epoch 33/80

Loss: 1.0853 Acc: 0.5683 LR: 0.00010000

Epoch 34/80

Loss: 1.0903 Acc: 0.5663 LR: 0.00001000

Epoch 35/80

Loss: 1.0921 Acc: 0.5652 LR: 0.00001000

Epoch 36/80

Loss: 1.0891 Acc: 0.5679 LR: 0.00001000

Epoch 37/80

Loss: 1.0922 Acc: 0.5653 LR: 0.00001000

Epoch 38/80

Loss: 1.0895 Acc: 0.5639 LR: 0.00001000

Epoch 39/80

Loss: 1.0835 Acc: 0.5676 LR: 0.00001000

Epoch 40/80

Loss: 1.0889 Acc: 0.5665 LR: 0.00001000

Epoch 41/80

Loss: 1.0931 Acc: 0.5641 LR: 0.00001000

Epoch 42/80

Loss: 1.0854 Acc: 0.5653 LR: 0.00001000

Epoch 43/80

Loss: 1.0865 Acc: 0.5682 LR: 0.00001000

Epoch 44/80

Loss: 1.0924 Acc: 0.5637 LR: 0.00001000

```
Epoch 45/80
----------
Loss: 1.0844 Acc: 0.5686 LR: 0.00001000

Epoch 46/80
----------
Loss: 1.0856 Acc: 0.5675 LR: 0.00001000

Epoch 47/80
----------
Loss: 1.0906 Acc: 0.5638 LR: 0.00001000

Epoch 48/80
----------
Loss: 1.0891 Acc: 0.5663 LR: 0.00001000

Epoch 49/80
----------
Loss: 1.0863 Acc: 0.5664 LR: 0.00001000

Epoch 50/80
----------
Loss: 1.0899 Acc: 0.5665 LR: 0.00000100

Epoch 51/80
----------
Loss: 1.0852 Acc: 0.5684 LR: 0.00000100

Epoch 52/80
----------
Loss: 1.0832 Acc: 0.5716 LR: 0.00000100

Epoch 53/80
----------
Loss: 1.0867 Acc: 0.5689 LR: 0.00000100

Epoch 54/80
----------
Loss: 1.0850 Acc: 0.5672 LR: 0.00000100

Epoch 55/80
----------
Loss: 1.0909 Acc: 0.5681 LR: 0.00000100

Epoch 56/80
----------
Loss: 1.0844 Acc: 0.5686 LR: 0.00000100

Epoch 57/80
----------
```

```
Loss: 1.0867 Acc: 0.5686 LR: 0.00000100

Epoch 58/80
----------
Loss: 1.0871 Acc: 0.5679 LR: 0.00000100

Epoch 59/80
----------
Loss: 1.0903 Acc: 0.5664 LR: 0.00000100

Epoch 60/80
----------
Loss: 1.0858 Acc: 0.5717 LR: 0.00000100

Epoch 61/80
----------
Loss: 1.0901 Acc: 0.5665 LR: 0.00000100

Epoch 62/80
----------
Loss: 1.0879 Acc: 0.5695 LR: 0.00000100

Epoch 63/80
----------
Loss: 1.0895 Acc: 0.5686 LR: 0.00000100

Epoch 64/80
----------
Loss: 1.0851 Acc: 0.5675 LR: 0.00000100

Epoch 65/80
----------
Loss: 1.0886 Acc: 0.5685 LR: 0.00000100

Epoch 66/80
----------
Loss: 1.0886 Acc: 0.5669 LR: 0.00000100

Epoch 67/80
----------
Loss: 1.0832 Acc: 0.5672 LR: 0.00000100

Epoch 68/80
----------
Loss: 1.0887 Acc: 0.5662 LR: 0.00000100

Epoch 69/80
----------
Loss: 1.0865 Acc: 0.5646 LR: 0.00000100
```

```
Epoch 70/80
----------
Loss: 1.0883 Acc: 0.5665 LR: 0.00000010

Epoch 71/80
----------
Loss: 1.0857 Acc: 0.5654 LR: 0.00000010

Epoch 72/80
----------
Loss: 1.0850 Acc: 0.5709 LR: 0.00000010

Epoch 73/80
----------
Loss: 1.0835 Acc: 0.5706 LR: 0.00000010

Epoch 74/80
----------
Loss: 1.0867 Acc: 0.5709 LR: 0.00000010

Epoch 75/80
----------
Loss: 1.0914 Acc: 0.5676 LR: 0.00000010

Epoch 76/80
----------
Loss: 1.0919 Acc: 0.5656 LR: 0.00000010

Epoch 77/80
----------
Loss: 1.0835 Acc: 0.5732 LR: 0.00000010

Epoch 78/80
----------
Loss: 1.0888 Acc: 0.5692 LR: 0.00000010

Epoch 79/80
----------
Loss: 1.0861 Acc: 0.5654 LR: 0.00000010

Epoch 80/80
----------
Loss: 1.0821 Acc: 0.5693 LR: 0.00000010

Training complete in 559m 1s
Best Acc: 0.573200
```

In [ ]:

```
time.sleep(5)  # Sleep for 5 seconds to let the system cool down
```

```
from google.colab import runtime
runtime.unassign()
```

In [ ]:

```
```