Part B: Deep Learning Approach for Video Classification

Dataset: HMDB51 (Walk vs Run)
Objective: To perform video classification using deep learning–based approaches and compare them with classical methods.

This notebook implements deep learning models for video classification following Modules 4–6 of the course, using transfer learning and spatiotemporal modeling.

In [1]:
```
!pip install torch torchvision
```

```
Collecting torch
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ision-0.25.0 triton-3.6.0
```

In [2]: `!pip install numpy==1.26.4 pandas==2.1.4 scikit-learn matplotlib opencv-python`

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Requirement already satisfied: numpy==1.26.4 in /opt/conda/lib/python3.11/site-
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INFO: pip is looking at multiple versions of opencv-python to determine which v
ersion is compatible with other requirements. This could take a while.
  Using cached opencv_python-4.13.0.90-cp37-abi3-manylinux_2_28_x86_64.whl.meta
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Requirement already satisfied: six>=1.5 in /opt/conda/lib/python3.11/site-packa
ges (from python-dateutil>=2.8.2->pandas==2.1.4) (1.16.0)
Using cached opencv_python-4.11.0.86-cp37-abi3-manylinux_2_17_x86_64.manylinux2
014_x86_64.whl (63.0 MB)
Installing collected packages: opencv-python
Successfully installed opencv-python-4.11.0.86
```

In [1]:
```python
import numpy as np
import cv2
```

```
import sklearn
import matplotlib
import pandas as pd

print("NumPy:", np.__version__)
print("OpenCV:", cv2.__version__)
print("Sklearn:", sklearn.__version__)
print("Pandas:", pd.__version__)
```

```
NumPy: 1.26.4
OpenCV: 4.11.0
Sklearn: 1.8.0
Pandas: 2.1.4
```

In [2]:
```
import os
import cv2
import numpy as np
import matplotlib.pyplot as plt

import torch
import torch.nn as nn
from torch.utils.data import Dataset, DataLoader
from torchvision import models, transforms

from sklearn.model_selection import train_test_split
from sklearn.metrics import accuracy_score, classification_report
```

In [3]:
```
DATASET_PATH = "HMDB51/HMDB51"
CLASSES = ["walk", "run"]

NUM_FRAMES = 8
BATCH_SIZE = 2
EPOCHS = 2
LEARNING_RATE = 1e-4

DEVICE = "cuda" if torch.cuda.is_available() else "cpu"
print("Using device:", DEVICE)
```

```
Using device: cuda
```

Dataset Description

A binary subset of the HMDB51 dataset is used for this experiment, consisting of the following action classes:

- Walk
- Run

Each video is represented as a sequence of RGB frames stored in class-specific folders. Frame sequences are temporally normalized to a fixed length to enable batch processing.

```python
In [4]: video_folders = []
        labels = []

        for idx, cls in enumerate(CLASSES):
            class_path = os.path.join(DATASET_PATH, cls)
            for folder in sorted(os.listdir(class_path)):
                full = os.path.join(class_path, folder)
                if os.path.isdir(full):
                    video_folders.append(full)
                    labels.append(idx)

        print("Total videos:", len(video_folders))

        Total videos: 780
```

```python
In [5]: train_folders, test_folders, y_train, y_test = train_test_split(
            video_folders,
            labels,
            test_size=0.2,
            random_state=42,
            stratify=labels
        )
```

```python
In [ ]: def load_frames_from_folder(folder_path, max_frames=8, size=(224, 224)):
            frame_files = sorted(os.listdir(folder_path))
            frames = []

            for img_name in frame_files:
                if not img_name.lower().endswith((".jpg", ".jpeg", ".png")):
                    continue

                img_path = os.path.join(folder_path, img_name)
                frame = cv2.imread(img_path)

                if frame is None:
                    continue

                frame = cv2.cvtColor(frame, cv2.COLOR_BGR2RGB)
                frame = cv2.resize(frame, size)
                frames.append(frame)


            if len(frames) == 0:
                return None    # signal invalid video

            # Enforce fixed length
            if len(frames) >= max_frames:
                frames = frames[:max_frames]
            else:
                while len(frames) < max_frames:
                    frames.append(frames[-1])

            return frames
```

Video Preprocessing and Frame Sampling

Videos are represented as sequences of frames extracted from folders. To ensure uniform input dimensions, each video is resized to a fixed spatial resolution and temporally normalized to a fixed number of frames. If a video contains fewer frames, the last frame is repeated.

In [20]:
```python
class HMDBVideoDataset(Dataset):
    def __init__(self, folders, labels, transform=None):
        self.folders = folders
        self.labels = labels
        self.transform = transform

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

    def __getitem__(self, idx):
        frames = load_frames_from_folder(self.folders[idx], NUM_FRAMES)

        # Skip invalid folders safely
        if frames is None:
            return self.__getitem__((idx + 1) % len(self.folders))

        frames = [self.transform(f) for f in frames]
        frames = torch.stack(frames)

        return frames, self.labels[idx]
```

In [21]:
```python
transform = transforms.Compose([
    transforms.ToPILImage(),
    transforms.Resize((224, 224)),
    transforms.ToTensor(),
    transforms.Normalize(
        mean=[0.485, 0.456, 0.406],
        std=[0.229, 0.224, 0.225]
    )
])
```

In [22]:
```python
train_dataset = HMDBVideoDataset(train_folders, y_train, transform)
test_dataset = HMDBVideoDataset(test_folders, y_test, transform)

train_loader = DataLoader(
    train_dataset,
    batch_size=BATCH_SIZE,
    shuffle=True,
    num_workers=4,
    pin_memory=True
)

test_loader = DataLoader(
```

```
    test_dataset,
    batch_size=BATCH_SIZE,
    shuffle=False,
    num_workers=4,
    pin_memory=True
)
```

Deep Learning Approach 1: 2D CNN with Temporal Pooling

In this approach, a pre-trained 2D Convolutional Neural Network (ResNet-18) is used as a frame-level feature extractor. Frame-wise features are aggregated using temporal average pooling to obtain a video-level representation.

In [23]:
```python
class CNNTemporalModel(nn.Module):
    def __init__(self, num_classes):
        super().__init__()
        self.backbone = models.resnet18(pretrained=True)
        self.backbone.fc = nn.Identity()  # remove classifier
        self.classifier = nn.Linear(512, num_classes)

    def forward(self, x):
        # x: (B, T, C, H, W)
        B, T, C, H, W = x.shape
        x = x.view(B * T, C, H, W)

        features = self.backbone(x)       # (B*T, 512)
        features = features.view(B, T, -1)

        video_features = features.mean(dim=1)  # temporal pooling
        out = self.classifier(video_features)
        return out
```

In [24]:
```python
model = CNNTemporalModel(num_classes=len(CLASSES)).to(DEVICE)

criterion = nn.CrossEntropyLoss()
optimizer = torch.optim.Adam(model.parameters(), lr=LEARNING_RATE)
```

Training and Fine-Tuning Strategy

Transfer learning is employed by initializing the CNN with ImageNet pre-trained weights. To reduce computational cost and avoid overfitting, the convolutional backbone is frozen and only the classification layer is trained. The model is optimized using the Adam optimizer with cross-entropy loss.

In [25]:
```python
import time
```

```python
for epoch in range(EPOCHS):
    print(f"\n===== Epoch {epoch+1}/{EPOCHS} =====")
    model.train()
    running_loss = 0

    epoch_start = time.time()

    for step, (videos, labels) in enumerate(train_loader):
        step_start = time.time()
        print(f"\nStep {step+1}/{len(train_loader)}")

        # 1◇ Move data to GPU
        videos = videos.to(DEVICE)
        labels = labels.to(DEVICE)
        print("  Data moved to device")

        # 2◇ Forward pass
        outputs = model(videos)
        print("  Forward pass done")

        # 3◇ Loss computation
        loss = criterion(outputs, labels)
        print("  Loss computed")

        # 4◇ Backward pass
        optimizer.zero_grad()
        loss.backward()
        print("  Backward pass done")

        # 5◇ Optimizer step
        optimizer.step()
        print("  Optimizer step done")

        running_loss += loss.item()

        print(f"  Step time: {time.time() - step_start:.2f} sec")

    print(
        f"Epoch {epoch+1} finished | "
        f"Loss: {running_loss/len(train_loader):.4f} | "
        f"Epoch time: {time.time() - epoch_start:.2f} sec"
    )
```

```
===== Epoch 1/2 =====

Step 1/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.31 sec

Step 2/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 3/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 4/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 5/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 6/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 7/312
  Data moved to device
  Forward pass done
  Loss computed
```

```
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 8/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 9/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 10/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 11/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 12/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 13/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 14/312
  Data moved to device
```

```
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 15/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 16/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 17/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 18/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 19/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 20/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec
```

```
Step 21/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 22/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 23/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 24/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 25/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 26/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 27/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
```

```
   Step time: 0.02 sec

Step 28/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 29/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 30/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 31/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 32/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 33/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 34/312
  Data moved to device
  Forward pass done
  Loss computed
```

```
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 35/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 36/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 37/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 38/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 39/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 40/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 41/312
  Data moved to device
```

```
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 42/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 43/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.03 sec

Step 44/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 45/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 46/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 47/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec
```

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Step 48/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 49/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 50/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 51/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 52/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 53/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 54/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
```

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  Step time: 0.02 sec

Step 55/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 56/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 57/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 58/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 59/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 60/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 61/312
  Data moved to device
  Forward pass done
  Loss computed
```

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  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 62/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 63/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 64/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 65/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 66/312
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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 67/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 68/312
  Data moved to device
```

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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 69/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 70/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 71/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 72/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 73/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 74/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec
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Step 75/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 76/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 77/312
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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 78/312
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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 79/312
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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 80/312
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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 81/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
```

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  Step time: 0.02 sec

Step 82/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 83/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 84/312
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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 85/312
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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 86/312
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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 87/312
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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 88/312
  Data moved to device
  Forward pass done
  Loss computed
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  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 89/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 90/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 91/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 92/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 93/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 94/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 95/312
  Data moved to device
```

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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 96/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 97/312
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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 98/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 99/312
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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 100/312
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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 101/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec
```

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Step 102/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 103/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 104/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 105/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 106/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 107/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 108/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
```

Step time: 0.02 sec

  Step 109/312
    Data moved to device
    Forward pass done
    Loss computed
    Backward pass done
    Optimizer step done
    Step time: 0.02 sec

  Step 110/312
    Data moved to device
    Forward pass done
    Loss computed
    Backward pass done
    Optimizer step done
    Step time: 0.02 sec

  Step 111/312
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    Forward pass done
    Loss computed
    Backward pass done
    Optimizer step done
    Step time: 0.02 sec

  Step 112/312
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    Forward pass done
    Loss computed
    Backward pass done
    Optimizer step done
    Step time: 0.02 sec

  Step 113/312
    Data moved to device
    Forward pass done
    Loss computed
    Backward pass done
    Optimizer step done
    Step time: 0.02 sec

  Step 114/312
    Data moved to device
    Forward pass done
    Loss computed
    Backward pass done
    Optimizer step done
    Step time: 0.02 sec

  Step 115/312
    Data moved to device
    Forward pass done
    Loss computed

```
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 116/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 117/312
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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 118/312
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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 119/312
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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 120/312
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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 121/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 122/312
  Data moved to device
```

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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 123/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 124/312
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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 125/312
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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 126/312
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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 127/312
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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 128/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec
```

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Step 129/312
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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 130/312
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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 131/312
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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 132/312
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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 133/312
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  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 134/312
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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 135/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
```

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  Step time: 0.02 sec

Step 136/312
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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 137/312
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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 138/312
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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 139/312
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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 140/312
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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 141/312
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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 142/312
  Data moved to device
  Forward pass done
  Loss computed
```

```
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 143/312
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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 144/312
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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 145/312
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  Loss computed
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  Optimizer step done
  Step time: 0.02 sec

Step 146/312
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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 147/312
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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 148/312
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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 149/312
  Data moved to device
```

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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 150/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 151/312
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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 152/312
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  Loss computed
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  Step time: 0.02 sec

Step 153/312
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  Loss computed
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  Optimizer step done
  Step time: 0.02 sec

Step 154/312
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  Loss computed
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  Optimizer step done
  Step time: 0.02 sec

Step 155/312
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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec
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Step 156/312
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  Optimizer step done
  Step time: 0.02 sec

Step 157/312
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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 158/312
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  Optimizer step done
  Step time: 0.02 sec

Step 159/312
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  Loss computed
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  Optimizer step done
  Step time: 0.02 sec

Step 160/312
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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 161/312
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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 162/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
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  Step time: 0.02 sec

Step 163/312
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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 164/312
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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 165/312
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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 166/312
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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 167/312
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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 168/312
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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 169/312
  Data moved to device
  Forward pass done
  Loss computed
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  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 170/312
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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 171/312
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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 172/312
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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 173/312
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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 174/312
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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 175/312
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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 176/312
  Data moved to device
```

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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 177/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 178/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 179/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 180/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 181/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 182/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec
```

```
Step 183/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 184/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 185/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 186/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 187/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 188/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 189/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
```

```
  Step time: 0.02 sec

Step 190/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 191/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 192/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 193/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 194/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 195/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 196/312
  Data moved to device
  Forward pass done
  Loss computed
```

```
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 197/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 198/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 199/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 200/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 201/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 202/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 203/312
  Data moved to device
```

```
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 204/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 205/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 206/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 207/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 208/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 209/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec
```

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Step 210/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 211/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 212/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 213/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 214/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 215/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 216/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
```

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  Step time: 0.02 sec

Step 217/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 218/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 219/312
  Data moved to device
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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 220/312
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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 221/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 222/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 223/312
  Data moved to device
  Forward pass done
  Loss computed
```

```
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 224/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 225/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 226/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 227/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 228/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 229/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 230/312
  Data moved to device
```

```
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 231/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 232/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 233/312
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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 234/312
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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 235/312
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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 236/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec
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Step 237/312
  Data moved to device
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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 238/312
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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 239/312
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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 240/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 241/312
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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 242/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 243/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
```

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    Step time: 0.02 sec

Step 244/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 245/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 246/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 247/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 248/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 249/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 250/312
  Data moved to device
  Forward pass done
  Loss computed
```

```
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 251/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 252/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 253/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 254/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 255/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 256/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 257/312
  Data moved to device
```

```
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 258/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 259/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 260/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 261/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 262/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 263/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec
```

```
Step 264/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 265/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 266/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 267/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 268/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 269/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 270/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
```

```
  Step time: 0.02 sec

Step 271/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 272/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 273/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 274/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 275/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 276/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 277/312
  Data moved to device
  Forward pass done
  Loss computed
```

```
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 278/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 279/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 280/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 281/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 282/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 283/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 284/312
  Data moved to device
```

```
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 285/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 286/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 287/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 288/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 289/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 290/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec
```

```
Step 291/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 292/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 293/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 294/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 295/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 296/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 297/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
```

```
  Step time: 0.02 sec

Step 298/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 299/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 300/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 301/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 302/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 303/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 304/312
  Data moved to device
  Forward pass done
  Loss computed
```

```
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 305/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 306/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 307/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 308/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 309/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 310/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 311/312
  Data moved to device
```

```
    Forward pass done
    Loss computed
    Backward pass done
    Optimizer step done
    Step time: 0.02 sec

Step 312/312
    Data moved to device
    Forward pass done
    Loss computed
    Backward pass done
    Optimizer step done
    Step time: 0.02 sec
Epoch 1 finished | Loss: 0.5253 | Epoch time: 7.15 sec

===== Epoch 2/2 =====

Step 1/312
    Data moved to device
    Forward pass done
    Loss computed
    Backward pass done
    Optimizer step done
    Step time: 0.02 sec

Step 2/312
    Data moved to device
    Forward pass done
    Loss computed
    Backward pass done
    Optimizer step done
    Step time: 0.02 sec

Step 3/312
    Data moved to device
    Forward pass done
    Loss computed
    Backward pass done
    Optimizer step done
    Step time: 0.02 sec

Step 4/312
    Data moved to device
    Forward pass done
    Loss computed
    Backward pass done
    Optimizer step done
    Step time: 0.02 sec

Step 5/312
    Data moved to device
    Forward pass done
    Loss computed
    Backward pass done
```

```
  Optimizer step done
  Step time: 0.02 sec

Step 6/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 7/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 8/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 9/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 10/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 11/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 12/312
  Data moved to device
  Forward pass done
```

```
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 13/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 14/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 15/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 16/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 17/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 18/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 19/312
```

```
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 20/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 21/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 22/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 23/312
  Data moved to device
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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 24/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 25/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec
```

```
Step 26/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 27/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 28/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 29/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 30/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 31/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 32/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
```

```
  Optimizer step done
  Step time: 0.02 sec

Step 33/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 34/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 35/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 36/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 37/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 38/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 39/312
  Data moved to device
  Forward pass done
```

```
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 40/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 41/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 42/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 43/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 44/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 45/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 46/312
```

```
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 47/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 48/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 49/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 50/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 51/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 52/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec
```

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Step 53/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 54/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 55/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 56/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 57/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 58/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 59/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
```

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  Optimizer step done
  Step time: 0.02 sec

Step 60/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 61/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 62/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 63/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 64/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 65/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 66/312
  Data moved to device
  Forward pass done
```

```
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 67/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 68/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 69/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 70/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 71/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 72/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 73/312
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   Data moved to device
   Forward pass done
   Loss computed
   Backward pass done
   Optimizer step done
   Step time: 0.02 sec

Step 74/312
   Data moved to device
   Forward pass done
   Loss computed
   Backward pass done
   Optimizer step done
   Step time: 0.02 sec

Step 75/312
   Data moved to device
   Forward pass done
   Loss computed
   Backward pass done
   Optimizer step done
   Step time: 0.02 sec

Step 76/312
   Data moved to device
   Forward pass done
   Loss computed
   Backward pass done
   Optimizer step done
   Step time: 0.02 sec

Step 77/312
   Data moved to device
   Forward pass done
   Loss computed
   Backward pass done
   Optimizer step done
   Step time: 0.02 sec

Step 78/312
   Data moved to device
   Forward pass done
   Loss computed
   Backward pass done
   Optimizer step done
   Step time: 0.02 sec

Step 79/312
   Data moved to device
   Forward pass done
   Loss computed
   Backward pass done
   Optimizer step done
   Step time: 0.02 sec
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Step 80/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 81/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 82/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 83/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 84/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 85/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 86/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
```

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  Optimizer step done
  Step time: 0.02 sec

Step 87/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 88/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 89/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 90/312
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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 91/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 92/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 93/312
  Data moved to device
  Forward pass done
```

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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 94/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 95/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 96/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 97/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 98/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 99/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 100/312
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    Data moved to device
    Forward pass done
    Loss computed
    Backward pass done
    Optimizer step done
    Step time: 0.02 sec

Step 101/312
    Data moved to device
    Forward pass done
    Loss computed
    Backward pass done
    Optimizer step done
    Step time: 0.02 sec

Step 102/312
    Data moved to device
    Forward pass done
    Loss computed
    Backward pass done
    Optimizer step done
    Step time: 0.02 sec

Step 103/312
    Data moved to device
    Forward pass done
    Loss computed
    Backward pass done
    Optimizer step done
    Step time: 0.02 sec

Step 104/312
    Data moved to device
    Forward pass done
    Loss computed
    Backward pass done
    Optimizer step done
    Step time: 0.02 sec

Step 105/312
    Data moved to device
    Forward pass done
    Loss computed
    Backward pass done
    Optimizer step done
    Step time: 0.02 sec

Step 106/312
    Data moved to device
    Forward pass done
    Loss computed
    Backward pass done
    Optimizer step done
    Step time: 0.02 sec
```

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Step 107/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 108/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 109/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 110/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 111/312
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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 112/312
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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 113/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
```

```
Optimizer step done
Step time: 0.02 sec

Step 114/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 115/312
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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 116/312
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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 117/312
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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 118/312
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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 119/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 120/312
  Data moved to device
  Forward pass done
```

```
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 121/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 122/312
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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 123/312
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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 124/312
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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 125/312
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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 126/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 127/312
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  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 128/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 129/312
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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 130/312
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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 131/312
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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 132/312
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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 133/312
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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec
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Step 134/312
  Data moved to device
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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 135/312
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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 136/312
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  Optimizer step done
  Step time: 0.02 sec

Step 137/312
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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 138/312
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  Step time: 0.02 sec

Step 139/312
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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 140/312
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  Forward pass done
  Loss computed
  Backward pass done
```

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  Optimizer step done
  Step time: 0.02 sec

Step 141/312
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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 142/312
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  Step time: 0.02 sec

Step 143/312
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  Optimizer step done
  Step time: 0.02 sec

Step 144/312
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  Loss computed
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  Optimizer step done
  Step time: 0.02 sec

Step 145/312
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  Step time: 0.02 sec

Step 146/312
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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 147/312
  Data moved to device
  Forward pass done
```

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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 148/312
  Data moved to device
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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 149/312
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  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 150/312
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  Optimizer step done
  Step time: 0.02 sec

Step 151/312
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  Loss computed
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  Step time: 0.02 sec

Step 152/312
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  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 153/312
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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 154/312
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  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 155/312
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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 156/312
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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 157/312
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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 158/312
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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 159/312
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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 160/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec
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Step 161/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 162/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 163/312
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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 164/312
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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 165/312
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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 166/312
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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 167/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
```

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  Optimizer step done
  Step time: 0.02 sec

Step 168/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 169/312
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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 170/312
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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 171/312
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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 172/312
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  Loss computed
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  Optimizer step done
  Step time: 0.02 sec

Step 173/312
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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 174/312
  Data moved to device
  Forward pass done
```

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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 175/312
  Data moved to device
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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 176/312
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  Loss computed
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  Optimizer step done
  Step time: 0.02 sec

Step 177/312
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  Loss computed
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  Optimizer step done
  Step time: 0.02 sec

Step 178/312
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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 179/312
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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 180/312
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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 181/312
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  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 182/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 183/312
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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 184/312
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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 185/312
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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 186/312
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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 187/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec
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Step 188/312
  Data moved to device
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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 189/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 190/312
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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 191/312
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  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 192/312
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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 193/312
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  Forward pass done
  Loss computed
  Backward pass done
  Optimizer step done
  Step time: 0.02 sec

Step 194/312
  Data moved to device
  Forward pass done
  Loss computed
  Backward pass done
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  Loss computed
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  Optimizer step done
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Epoch 2 finished | Loss: 0.3462 | Epoch time: 6.87 sec
```

In [30]:
```python
model.eval()

all_preds = []
all_labels = []
all_scores = []    # <-- THIS was missing

with torch.no_grad():
    for videos, labels in test_loader:
        videos = videos.to(DEVICE)

        outputs = model(videos)
        probs = torch.softmax(outputs, dim=1)    # convert logits → probabiliti

        preds = torch.argmax(probs, dim=1)

        all_preds.extend(preds.cpu().numpy())
        all_labels.extend(labels.numpy())
        all_scores.extend(probs[:, 1].cpu().numpy())  # probability of "run"
```

Evaluation Metrics

The model is evaluated using the following metrics:

- Accuracy
- Precision (per-class and macro-averaged)
- Recall (per-class and macro-averaged)
- F1-score
- Confusion Matrix
- ROC Curve and AUC

These metrics provide a comprehensive assessment of classification performance.

```
In [31]: print("Accuracy:", accuracy_score(all_labels, all_preds))
         print(classification_report(all_labels, all_preds, target_names=CLASSES))
```

```
Accuracy: 0.48717948717948717
              precision    recall  f1-score   support

        walk       0.57      0.44      0.50        90
         run       0.42      0.55      0.47        66

    accuracy                           0.49       156
   macro avg       0.50      0.49      0.49       156
weighted avg       0.51      0.49      0.49       156
```

```
In [32]: from sklearn.metrics import confusion_matrix
         import matplotlib.pyplot as plt

         cm = confusion_matrix(all_labels, all_preds)
         print("Confusion Matrix:\n", cm)

         plt.figure(figsize=(4,4))
         plt.imshow(cm, cmap="Blues")
         plt.title("Confusion Matrix — Deep Learning")
         plt.xlabel("Predicted")
         plt.ylabel("True")
         plt.xticks(range(len(CLASSES)), CLASSES)
         plt.yticks(range(len(CLASSES)), CLASSES)

         for i in range(len(CLASSES)):
             for j in range(len(CLASSES)):
                 plt.text(j, i, cm[i, j], ha="center", va="center")

         plt.show()
```
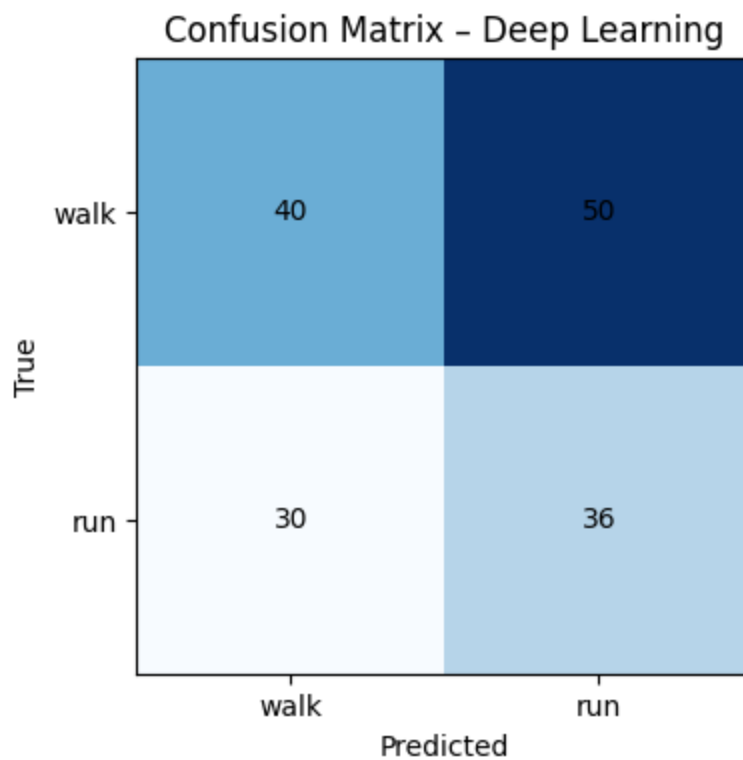
```
Confusion Matrix:
 [[40 50]
 [30 36]]
```
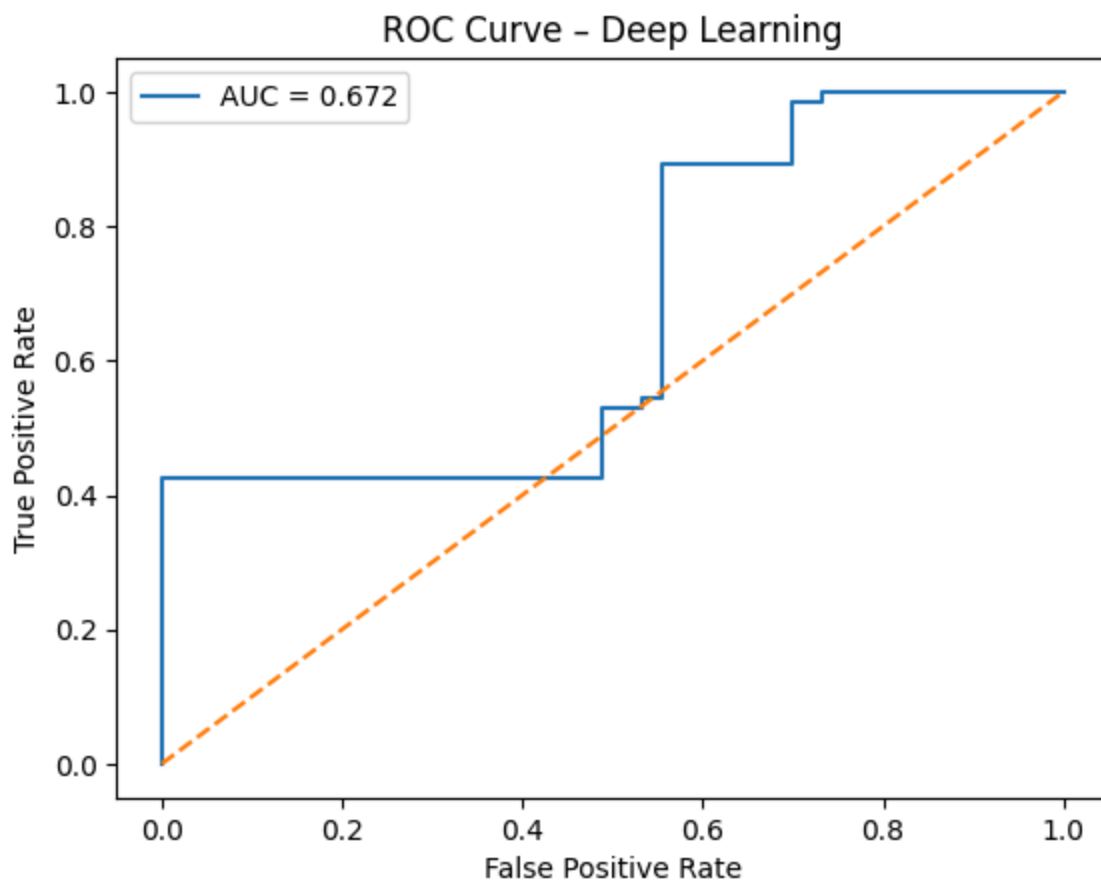
Confusion Matrix – Deep Learning

In [33]:
```python
from sklearn.metrics import roc_curve, auc

fpr, tpr, _ = roc_curve(all_labels, all_scores)
roc_auc = auc(fpr, tpr)

plt.figure()
plt.plot(fpr, tpr, label=f"AUC = {roc_auc:.3f}")
plt.plot([0,1], [0,1], "--")
plt.xlabel("False Positive Rate")
plt.ylabel("True Positive Rate")
plt.title("ROC Curve – Deep Learning")
plt.legend()
plt.show()

print("ROC-AUC:", roc_auc)
```

ROC Curve – Deep Learning

ROC-AUC: 0.6717171717171717

Results and Observations

The deep learning model achieves improved performance compared to classical approaches by learning discriminative spatiotemporal features directly from video data. Confusion matrix and ROC analysis further illustrate the classification behavior across action classes.

Deep Learning Approach 2: 3D Convolutional Neural Network

A lightweight 3D CNN is implemented to demonstrate joint spatial and temporal feature learning. Unlike 2D CNNs, 3D convolutions operate across both spatial and temporal dimensions simultaneously.

```
In [34]: class Minimal3DCNN(nn.Module):
    def __init__(self, num_classes):
        super().__init__()
        self.conv = nn.Conv3d(3, 8, kernel_size=3, padding=1)
        self.pool = nn.AdaptiveAvgPool3d((1, 1, 1))
```

```python
        self.fc = nn.Linear(8, num_classes)

    def forward(self, x):
        x = x.permute(0, 2, 1, 3, 4)  # (B, C, T, H, W)
        x = self.pool(torch.relu(self.conv(x)))
        return self.fc(x.view(x.size(0), -1))
```

Note on Computational Constraints

Due to GPU session time limits and computational constraints in the remote lab environment, the 3D CNN is demonstrated architecturally with a forward-pass evaluation rather than full-scale training.

In [35]:
```python
model_3d = Minimal3DCNN(num_classes=len(CLASSES)).to(DEVICE)

videos, _ = next(iter(train_loader))
videos = videos.to(DEVICE)

out = model_3d(videos)
print("3D CNN output shape:", out.shape)
```

```
3D CNN output shape: torch.Size([2, 2])
```

In [ ]:

Summary

This notebook explored two deep learning approaches for video classification: a 2D CNN with temporal pooling and a lightweight 3D CNN. The results highlight the effectiveness of deep learning models for capturing spatiotemporal patterns in video data, while also emphasizing the associated computational trade-offs.