Preparation

- Run the code below before proceeding with the homework.
- If an error occurs, click 'Run Session Again' and then restart the runtime from the beginning.

```
!git clone https://github.com/mlvlab/ProMetaR.git
%cd ProMetaR/

!git clone https://github.com/KaiyangZhou/Dassl.pytorch.git
%cd Dassl.pytorch/

# Install dependencies
!pip install -r requirements.txt
!cp -r dassl ../
# Install this library (no need to re-build if the source code is modified)
# !python setup.py develop
%cd ..

!pip install -r requirements.txt

%mkdir outputs
%mkdir data
%cd data
%mkdir eurosat
!wget http://madm.dfki.de/files/sentinel/EuroSAT.zip -O EuroSAT.zip

!unzip -o EuroSAT.zip -d eurosat/
%cd eurosat
!gdown 1lp7yaCWFi0ea0FUGga0lUdVi_DDQth1o

%cd ../../

import os.path as osp
from collections import OrderedDict
import math
import torch
import torch.nn as nn
from torch.nn import functional as F
from torch.cuda.amp import GradScaler, autocast
from PIL import Image
import torchvision.transforms as transforms
import torch
from clip import clip
from clip.simple_tokenizer import SimpleTokenizer as _Tokenizer
import time
from tqdm import tqdm
import datetime
import argparse
from dassl.utils import setup_logger, set_random_seed, collect_env_info
from dassl.config import get_cfg_default
from dassl.engine import build_trainer
from dassl.engine import TRAINER_REGISTRY, TrainerX
from dassl.metrics import compute_accuracy
from dassl.utils import load_pretrained_weights, load_checkpoint
from dassl.optim import build_optimizer, build_lr_scheduler

# custom
import datasets.oxford_pets
import datasets.oxford_flowers
import datasets.fgvc_aircraft
import datasets.dtd
import datasets.eurosat
import datasets.stanford_cars
import datasets.food101
import datasets.sun397
import datasets.caltech101
import datasets.ucf101
import datasets.imagenet
import datasets.imagenet_sketch
import datasets.imagenetv2
import datasets.imagenet_a
import datasets.imagenet_r

def print_args(args, cfg):
    print("**********")
```

```
    print("** Arguments **")
    print("***************")
    optkeys = list(args.__dict__.keys())
    optkeys.sort()
    for key in optkeys:
      print("{}: {}".format(key, args.__dict__[key]))
    print("************")
    print("** Config **")
    print("************")
    print(cfg)

def reset_cfg(cfg, args):
    if args.root:
        cfg.DATASET.ROOT = args.root
    if args.output_dir:
        cfg.OUTPUT_DIR = args.output_dir
    if args.seed:
        cfg.SEED = args.seed
    if args.trainer:
        cfg.TRAINER.NAME = args.trainer
    cfg.DATASET.NUM_SHOTS = 16
    cfg.DATASET.SUBSAMPLE_CLASSES = args.subsample_classes
    cfg.DATALOADER.TRAIN_X.BATCH_SIZE = args.train_batch_size
    cfg.OPTIM.MAX_EPOCH = args.epoch

def extend_cfg(cfg):
    """
    Add new config variables.
    """
    from yacs.config import CfgNode as CN
    cfg.TRAINER.COOP = CN()
    cfg.TRAINER.COOP.N_CTX = 16  # number of context vectors
    cfg.TRAINER.COOP.CSC = False  # class-specific context
    cfg.TRAINER.COOP.CTX_INIT = ""  # initialization words
    cfg.TRAINER.COOP.PREC = "fp16"  # fp16, fp32, amp
    cfg.TRAINER.COOP.CLASS_TOKEN_POSITION = "end"  # 'middle' or 'end' or 'front'
    cfg.TRAINER.COCOOP = CN()
    cfg.TRAINER.COCOOP.N_CTX = 4  # number of context vectors
    cfg.TRAINER.COCOOP.CTX_INIT = "a photo of a"  # initialization words
    cfg.TRAINER.COCOOP.PREC = "fp16"  # fp16, fp32, amp
    cfg.TRAINER.PROMETAR = CN()
    cfg.TRAINER.PROMETAR.N_CTX_VISION = 4  # number of context vectors at the vision branch
    cfg.TRAINER.PROMETAR.N_CTX_TEXT = 4  # number of context vectors at the language branch
    cfg.TRAINER.PROMETAR.CTX_INIT = "a photo of a"  # initialization words
    cfg.TRAINER.PROMETAR.PREC = "fp16"  # fp16, fp32, amp
    cfg.TRAINER.PROMETAR.PROMPT_DEPTH_VISION = 9  # Max 12, minimum 0, for 0 it will be using shallow I
    cfg.TRAINER.PROMETAR.PROMPT_DEPTH_TEXT = 9  # Max 12, minimum 0, for 0 it will be using shallow IVL
    cfg.DATASET.SUBSAMPLE_CLASSES = "all"  # all, base or new
    cfg.TRAINER.PROMETAR.ADAPT_LR = 0.0005
    cfg.TRAINER.PROMETAR.LR_RATIO = 0.0005
    cfg.TRAINER.PROMETAR.FAST_ADAPTATION = False
    cfg.TRAINER.PROMETAR.MIXUP_ALPHA = 0.5
    cfg.TRAINER.PROMETAR.MIXUP_BETA = 0.5
    cfg.TRAINER.PROMETAR.DIM_RATE=8
    cfg.OPTIM_VNET = CN()
    cfg.OPTIM_VNET.NAME = "adam"
    cfg.OPTIM_VNET.LR = 0.0003
    cfg.OPTIM_VNET.WEIGHT_DECAY = 5e-4
    cfg.OPTIM_VNET.MOMENTUM = 0.9
    cfg.OPTIM_VNET.SGD_DAMPNING = 0
    cfg.OPTIM_VNET.SGD_NESTEROV = False
    cfg.OPTIM_VNET.RMSPROP_ALPHA = 0.99
    cfg.OPTIM_VNET.ADAM_BETA1 = 0.9
    cfg.OPTIM_VNET.ADAM_BETA2 = 0.999
    cfg.OPTIM_VNET.STAGED_LR = False
    cfg.OPTIM_VNET.NEW_LAYERS = ()
    cfg.OPTIM_VNET.BASE_LR_MULT = 0.1
    # Learning rate scheduler
    cfg.OPTIM_VNET.LR_SCHEDULER = "single_step"
    # -1 or 0 means the stepsize is equal to max_epoch
    cfg.OPTIM_VNET.STEPSIZE = (-1, )
    cfg.OPTIM_VNET.GAMMA = 0.1
    cfg.OPTIM_VNET.MAX_EPOCH = 10
    # Set WARMUP_EPOCH larger than 0 to activate warmup training
    cfg.OPTIM_VNET.WARMUP_EPOCH = -1
    # Either linear or constant
    cfg.OPTIM_VNET.WARMUP_TYPE = "linear"
    # Constant learning rate when type=constant
    cfg.OPTIM_VNET.WARMUP_CONS_LR = 1e-5
    # Minimum learning rate when type=linear
```

```
    cfg.OPTIM_VNET.WARMUP_MIN_LR = 1e-5
    # Recount epoch for the next scheduler (last_epoch=-1)
    # Otherwise last_epoch=warmup_epoch
    cfg.OPTIM_VNET.WARMUP_RECOUNT = True

def setup_cfg(args):
    cfg = get_cfg_default()
    extend_cfg(cfg)
    # 1. From the dataset config file
    if args.dataset_config_file:
        cfg.merge_from_file(args.dataset_config_file)
    # 2. From the method config file
    if args.config_file:
        cfg.merge_from_file(args.config_file)
    # 3. From input arguments
    reset_cfg(cfg, args)
    cfg.freeze()
    return cfg

_tokenizer = _Tokenizer()

def load_clip_to_cpu(cfg): # Load CLIP
    backbone_name = cfg.MODEL.BACKBONE.NAME
    url = clip._MODELS[backbone_name]
    model_path = clip._download(url)
    try:
        # loading JIT archive
        model = torch.jit.load(model_path, map_location="cpu").eval()
        state_dict = None

    except RuntimeError:
        state_dict = torch.load(model_path, map_location="cpu")

    if cfg.TRAINER.NAME == "":
      design_trainer = "CoOp"
    else:
      design_trainer = cfg.TRAINER.NAME
    design_details = {"trainer": design_trainer,
                      "vision_depth": 0,
                      "language_depth": 0, "vision_ctx": 0,
                      "language_ctx": 0}
    model = clip.build_model(state_dict or model.state_dict(), design_details)

    return model

from dassl.config import get_cfg_default
cfg = get_cfg_default()
cfg.MODEL.BACKBONE.NAME = "ViT-B/16" # Set the vision encoder backbone of CLIP to ViT.
clip_model = load_clip_to_cpu(cfg)

class TextEncoder(nn.Module):
    def __init__(self, clip_model): # 초기화 하는 함수
        super().__init__()
        self.transformer = clip_model.transformer
        self.positional_embedding = clip_model.positional_embedding
        self.ln_final = clip_model.ln_final
        self.text_projection = clip_model.text_projection
        self.dtype = clip_model.dtype

    def forward(self, prompts, tokenized_prompts): # 모델 호출
        x = prompts + self.positional_embedding.type(self.dtype)
        x = x.permute(1, 0, 2)  # NLD -> LND
        x = self.transformer(x)
        x = x.permute(1, 0, 2)  # LND -> NLD
        x = self.ln_final(x).type(self.dtype)

        # x.shape = [batch_size, n_ctx, transformer.width]
        # take features from the eot embedding (eot_token is the highest number in each sequence)
        x = x[torch.arange(x.shape[0]), tokenized_prompts.argmax(dim=-1)] @ self.text_projection

        return x

@TRAINER_REGISTRY.register(force=True)
class CoCoOp(TrainerX):
    def check_cfg(self, cfg):
        assert cfg.TRAINER.COCOOP.PREC in ["fp16", "fp32", "amp"]

    def build_model(self):
        cfg = self.cfg
```

```
        cfg = self.cfg
        classnames = self.dm.dataset.classnames
        print(f"Loading CLIP (backbone: {cfg.MODEL.BACKBONE.NAME})")
        clip_model = load_clip_to_cpu(cfg)

        if cfg.TRAINER.COCOOP.PREC == "fp32" or cfg.TRAINER.COCOOP.PREC == "amp":
            # CLIP's default precision is fp16
            clip_model.float()

        print("Building custom CLIP")
        self.model = CoCoOpCustomCLIP(cfg, classnames, clip_model)

        print("Turning off gradients in both the image and the text encoder")
        name_to_update = "prompt_learner"

        for name, param in self.model.named_parameters():
            if name_to_update not in name:
                param.requires_grad_(False)

        # Double check
        enabled = set()
        for name, param in self.model.named_parameters():
            if param.requires_grad:
                enabled.add(name)
        print(f"Parameters to be updated: {enabled}")

        if cfg.MODEL.INIT_WEIGHTS:
            load_pretrained_weights(self.model.prompt_learner, cfg.MODEL.INIT_WEIGHTS)

        self.model.to(self.device)
        # NOTE: only give prompt_learner to the optimizer
        self.optim = build_optimizer(self.model.prompt_learner, cfg.OPTIM)
        self.sched = build_lr_scheduler(self.optim, cfg.OPTIM)
        self.register_model("prompt_learner", self.model.prompt_learner, self.optim, self.sched)

        self.scaler = GradScaler() if cfg.TRAINER.COCOOP.PREC == "amp" else None

        # Note that multi-gpu training could be slow because CLIP's size is
        # big, which slows down the copy operation in DataParallel
        device_count = torch.cuda.device_count()
        if device_count > 1:
            print(f"Multiple GPUs detected (n_gpus={device_count}), use all of them!")
            self.model = nn.DataParallel(self.model)

    def before_train(self):
        directory = self.cfg.OUTPUT_DIR
        if self.cfg.RESUME:
            directory = self.cfg.RESUME
        self.start_epoch = self.resume_model_if_exist(directory)

        # Remember the starting time (for computing the elapsed time)
        self.time_start = time.time()

    def forward_backward(self, batch):
        image, label = self.parse_batch_train(batch)

        model = self.model
        optim = self.optim
        scaler = self.scaler

        prec = self.cfg.TRAINER.COCOOP.PREC
        loss = model(image, label) # Input image 모델 통과
        optim.zero_grad()
        loss.backward() # Backward (역전파)
        optim.step() # 모델 parameter update

        loss_summary = {"loss": loss.item()}

        if (self.batch_idx + 1) == self.num_batches:
            self.update_lr()

        return loss_summary

    def parse_batch_train(self, batch):
        input = batch["img"]
        label = batch["label"]
        input = input.to(self.device)
        label = label.to(self.device)
        return input, label
```

```
def load_model(self, directory, epoch=None):
    if not directory:
        print("Note that load_model() is skipped as no pretrained model is given")
        return

    names = self.get_model_names()

    # By default, the best model is loaded
    model_file = "model-best.pth.tar"

    if epoch is not None:
        model_file = "model.pth.tar-" + str(epoch)

    for name in names:
        model_path = osp.join(directory, name, model_file)

        if not osp.exists(model_path):
            raise FileNotFoundError('Model not found at "{}"'.format(model_path))

        checkpoint = load_checkpoint(model_path)
        state_dict = checkpoint["state_dict"]
        epoch = checkpoint["epoch"]

        # Ignore fixed token vectors
        if "token_prefix" in state_dict:
            del state_dict["token_prefix"]

        if "token_suffix" in state_dict:
            del state_dict["token_suffix"]

        print("Loading weights to {} " 'from "{}" (epoch = {})'.format(name, model_path, epoch))
        # set strict=False
        self._models[name].load_state_dict(state_dict, strict=False)

def after_train(self):
    print("Finish training")

    do_test = not self.cfg.TEST.NO_TEST
    if do_test:
        if self.cfg.TEST.FINAL_MODEL == "best_val":
            print("Deploy the model with the best val performance")
            self.load_model(self.output_dir)
        else:
            print("Deploy the last-epoch model")
        acc = self.test()

    # Show elapsed time
    elapsed = round(time.time() - self.time_start)
    elapsed = str(datetime.timedelta(seconds=elapsed))
    print(f"Elapsed: {elapsed}")

    # Close writer
    self.close_writer()
        return acc

    def train(self):
        """Generic training loops."""
        self.before_train()
        for self.epoch in range(self.start_epoch, self.max_epoch):
            self.before_epoch()
            self.run_epoch()
            self.after_epoch()
        acc = self.after_train()
        return acc

parser = argparse.ArgumentParser()
parser.add_argument("--root", type=str, default="data/", help="path to dataset")
parser.add_argument("--output-dir", type=str, default="outputs/cocoop3", help="output directory")
parser.add_argument(
    "--seed", type=int, default=1, help="only positive value enables a fixed seed"
)
parser.add_argument(
    "--config-file", type=str, default="configs/trainers/ProMetaR/vit_b16_c2_ep10_batch4_4+4ctx.yaml",
)
parser.add_argument(
    "--dataset-config-file",
    type=str,
    default="configs/datasets/eurosat.yaml",
    help="path to config file for dataset setup",
```

```
)
parser.add_argument("--trainer", type=str, default="CoOp", help="name of trainer")
parser.add_argument("--eval-only", action="store_true", help="evaluation only")
parser.add_argument(
    "--model-dir",
    type=str,
    default="",
    help="load model from this directory for eval-only mode",
)
parser.add_argument("--train-batch-size", type=int, default=4)
parser.add_argument("--epoch", type=int, default=10)
parser.add_argument("--subsample-classes", type=str, default="base")
parser.add_argument(
    "--load-epoch", type=int, default=0, help="load model weights at this epoch for evaluation"
)
args = parser.parse_args([])

def main(args):
    cfg = setup_cfg(args)
    if cfg.SEED >= 0:
        set_random_seed(cfg.SEED)

    if torch.cuda.is_available() and cfg.USE_CUDA:
        torch.backends.cudnn.benchmark = True

    trainer = build_trainer(cfg)
    if args.eval_only:
        trainer.load_model(args.model_dir, epoch=args.load_epoch)
        acc = trainer.test()
        return acc

    acc = trainer.train()
    return acc
```

스트리밍 출력 내용이 길어서 마지막 5000줄이 삭제되었습니다.

```
  inflating: eurosat/2750/SeaLake/SeaLake_1465.jpg
  inflating: eurosat/2750/SeaLake/SeaLake_1817.jpg
  inflating: eurosat/2750/SeaLake/SeaLake_2902.jpg
  inflating: eurosat/2750/SeaLake/SeaLake_2570.jpg
  inflating: eurosat/2750/SeaLake/SeaLake_1004.jpg
  inflating: eurosat/2750/SeaLake/SeaLake_174.jpg
  inflating: eurosat/2750/SeaLake/SeaLake_2111.jpg
  inflating: eurosat/2750/SeaLake/SeaLake_2388.jpg
  inflating: eurosat/2750/SeaLake/SeaLake_1948.jpg
  inflating: eurosat/2750/SeaLake/SeaLake_838.jpg
  inflating: eurosat/2750/SeaLake/SeaLake_2738.jpg
  inflating: eurosat/2750/SeaLake/SeaLake_1999.jpg
  inflating: eurosat/2750/SeaLake/SeaLake_2359.jpg
  inflating: eurosat/2750/SeaLake/SeaLake_2660.jpg
  inflating: eurosat/2750/SeaLake/SeaLake_1775.jpg
  inflating: eurosat/2750/SeaLake/SeaLake_605.jpg
  inflating: eurosat/2750/SeaLake/SeaLake_2201.jpg
  inflating: eurosat/2750/SeaLake/SeaLake_264.jpg
  inflating: eurosat/2750/SeaLake/SeaLake_1314.jpg
  inflating: eurosat/2750/SeaLake/SeaLake_1810.jpg
  inflating: eurosat/2750/SeaLake/SeaLake_1462.jpg
  inflating: eurosat/2750/SeaLake/SeaLake_512.jpg
  inflating: eurosat/2750/SeaLake/SeaLake_960.jpg
  inflating: eurosat/2750/SeaLake/SeaLake_2577.jpg
  inflating: eurosat/2750/SeaLake/SeaLake_2905.jpg
  inflating: eurosat/2750/SeaLake/SeaLake_173.jpg
  inflating: eurosat/2750/SeaLake/SeaLake_1003.jpg
  inflating: eurosat/2750/SeaLake/SeaLake_2116.jpg
  inflating: eurosat/2750/SeaLake/SeaLake_1546.jpg
  inflating: eurosat/2750/SeaLake/SeaLake_1934.jpg
  inflating: eurosat/2750/SeaLake/SeaLake_844.jpg
  inflating: eurosat/2750/SeaLake/SeaLake_436.jpg
  inflating: eurosat/2750/SeaLake/SeaLake_391.jpg
  inflating: eurosat/2750/SeaLake/SeaLake_2821.jpg
  inflating: eurosat/2750/SeaLake/SeaLake_2453.jpg
  inflating: eurosat/2750/SeaLake/SeaLake_1127.jpg
  inflating: eurosat/2750/SeaLake/SeaLake_1680.jpg
  inflating: eurosat/2750/SeaLake/SeaLake_2032.jpg
  inflating: eurosat/2750/SeaLake/SeaLake_2795.jpg
  inflating: eurosat/2750/SeaLake/SeaLake_2744.jpg
  inflating: eurosat/2750/SeaLake/SeaLake_1651.jpg
  inflating: eurosat/2750/SeaLake/SeaLake_721.jpg
  inflating: eurosat/2750/SeaLake/SeaLake_2482.jpg
  inflating: eurosat/2750/SeaLake/SeaLake_2325.jpg
  inflating: eurosat/2750/SeaLake/SeaLake_23.jpg
  inflating: eurosat/2750/SeaLake/SeaLake_895.jpg
  inflating: eurosat/2750/SeaLake/SeaLake_340.jpg
  inflating: eurosat/2750/SeaLake/SeaLake_1597.jpg
```

```
inflating: eurosat/2750/SeaLake/SeaLake_1230.jpg
inflating: eurosat/2750/SeaLake/SeaLake_1709.jpg
inflating: eurosat/2750/SeaLake/SeaLake_679.jpg
inflating: eurosat/2750/SeaLake/SeaLake_218.jpg
inflating: eurosat/2750/SeaLake/SeaLake_1368.jpg
inflating: eurosat/2750/SeaLake/SeaLake_2979.jpg
inflating: eurosat/2750/SeaLake/SeaLake_309.jpg
inflating: eurosat/2750/SeaLake/SeaLake_1279.jpg
inflating: eurosat/2750/SeaLake/SeaLake_1618.jpg
```

Q1. Understanding and implementing CoCoOp

- We have learned how to define CoOp in Lab Session 4.
- The main difference between CoOp and CoCoOp is **meta network** to extract image tokens that is added to the text prompt.
- Based on the CoOp code given in Lab Session 4, fill-in-the-blank exercise (4 blanks!!) to test your understanding of critical parts of the CoCoOp.

```
import torch.nn as nn

class CoCoOpPromptLearner(nn.Module):
    def __init__(self, cfg, classnames, clip_model):
        super().__init__()
        n_cls = len(classnames)
        n_ctx = cfg.TRAINER.COCOOP.N_CTX
        ctx_init = cfg.TRAINER.COCOOP.CTX_INIT
        dtype = clip_model.dtype
        ctx_dim = clip_model.ln_final.weight.shape[0]
        vis_dim = clip_model.visual.output_dim
        clip_imsize = clip_model.visual.input_resolution
        cfg_imsize = cfg.INPUT.SIZE[0]
        assert cfg_imsize == clip_imsize, f"cfg_imsize ({cfg_imsize}) must equal to clip_imsize ({clip_imsize})"

        if ctx_init:
            # use given words to initialize context vectors
            ctx_init = ctx_init.replace("_", " ")
            n_ctx = len(ctx_init.split(" "))
            prompt = clip.tokenize(ctx_init)
            with torch.no_grad():
                embedding = clip_model.token_embedding(prompt).type(dtype)
            ctx_vectors = embedding[0, 1: 1 + n_ctx, :]
            prompt_prefix = ctx_init
        else:
            # random initialization
            ctx_vectors = torch.empty(n_ctx, ctx_dim, dtype=dtype)
            nn.init.normal_(ctx_vectors, std=0.02)
            prompt_prefix = " ".join(["X"] * n_ctx)

        print(f'Initial context: "{prompt_prefix}"')
        print(f"Number of context words (tokens): {n_ctx}")

        self.ctx = nn.Parameter(ctx_vectors)  # Wrap the initialized prompts above as parameters to make them trainable.

        ### Tokenize ###
        classnames = [name.replace("_", " ") for name in classnames]  # 예) "Forest"
        name_lens = [len(_tokenizer.encode(name)) for name in classnames]
        prompts = [prompt_prefix + " " + name + "." for name in classnames] # 예) "A photo of Forest."

        tokenized_prompts = torch.cat([clip.tokenize(p) for p in prompts]) # 예) [49406, 320, 1125, 539...]

        ####################################
        ####### Q1. Fill in the blank #######
        ########## Define Meta Net ##########
        self.meta_net = nn.Sequential(OrderedDict([
            ("linear1", nn.Linear(vis_dim, vis_dim // 16)),
            ("relu", nn.ReLU(inplace=True)),
            ("linear2", nn.Linear(vis_dim // 16, ctx_dim))
        ]))
        ####################################
        ## Hint: meta network is composed to linear layer, relu activation, and linear layer.


        if cfg.TRAINER.COCOOP.PREC == "fp16":
            self.meta_net.half()

        with torch.no_grad():
            embedding = clip_model.token_embedding(tokenized_prompts).type(dtype)
```

```
        # These token vectors will be saved when in save_model(),
        # but they should be ignored in load_model() as we want to use
        # those computed using the current class names
        self.register_buffer("token_prefix", embedding[:, :1, :])  # SOS
        self.register_buffer("token_suffix", embedding[:, 1 + n_ctx:, :])  # CLS, EOS
        self.n_cls = n_cls
        self.n_ctx = n_ctx
        self.tokenized_prompts = tokenized_prompts  # torch.Tensor
        self.name_lens = name_lens

    def construct_prompts(self, ctx, prefix, suffix, label=None):
        # dim0 is either batch_size (during training) or n_cls (during testing)
        # ctx: context tokens, with shape of (dim0, n_ctx, ctx_dim)
        # prefix: the sos token, with shape of (n_cls, 1, ctx_dim)
        # suffix: remaining tokens, with shape of (n_cls, *, ctx_dim)

        if label is not None:
            prefix = prefix[label]
            suffix = suffix[label]

        prompts = torch.cat(
            [
                prefix,  # (dim0, 1, dim)
                ctx,  # (dim0, n_ctx, dim)
                suffix,  # (dim0, *, dim)
            ],
            dim=1,
        )

        return prompts

    def forward(self, im_features):
        prefix = self.token_prefix
        suffix = self.token_suffix
        ctx = self.ctx  # (n_ctx, ctx_dim)



        ##############################################
        ########## Q2,3. Fill in the blank #########
        bias = self.meta_net(im_features)  # (batch, ctx_dim)
        bias = bias.unsqueeze(1)  # (batch, 1, ctx_dim)
        ctx = ctx.unsqueeze(0)  # (1, n_ctx, ctx_dim)
        ctx_shifted = ctx + bias  # (batch, n_ctx, ctx_dim)
        ##############################################
        ##############################################



        # Use instance-conditioned context tokens for all classes
        prompts = []
        for ctx_shifted_i in ctx_shifted:
            ctx_i = ctx_shifted_i.unsqueeze(0).expand(self.n_cls, -1, -1)
            pts_i = self.construct_prompts(ctx_i, prefix, suffix)  # (n_cls, n_tkn, ctx_dim)
            prompts.append(pts_i)
        prompts = torch.stack(prompts)

        return prompts


class CoCoOpCustomCLIP(nn.Module):
    def __init__(self, cfg, classnames, clip_model):
        super().__init__()
        self.prompt_learner = CoCoOpPromptLearner(cfg, classnames, clip_model)
        self.tokenized_prompts = self.prompt_learner.tokenized_prompts
        self.image_encoder = clip_model.visual
        self.text_encoder = TextEncoder(clip_model)
        self.logit_scale = clip_model.logit_scale
        self.dtype = clip_model.dtype

    def forward(self, image, label=None):
        tokenized_prompts = self.tokenized_prompts
        logit_scale = self.logit_scale.exp()

        image_features = self.image_encoder(image.type(self.dtype))
        image_features = image_features / image_features.norm(dim=-1, keepdim=True)


        ##########################################



```

```
########## Q4. Fill in the blank #########
prompts = self.prompt_learner(image_features)
##########################################
##########################################


logits = []
for pts_i, imf_i in zip(prompts, image_features):
    text_features = self.text_encoder(pts_i, tokenized_prompts)
    text_features = text_features / text_features.norm(dim=-1, keepdim=True)
    l_i = logit_scale * imf_i @ text_features.t()
    logits.append(l_i)
logits = torch.stack(logits)

if self.prompt_learner.training:
    return F.cross_entropy(logits, label)

return logits
```

Q2. Trainining CoCoOp

In this task, you will train CoCoOp on the EuroSAT dataset. If your implementation of CoCoOp in Question 1 is correct, the following code should execute without errors. Please submit the execution file so we can evaluate whether your code runs without any issues.

```
# Train on the Base Classes Train split and evaluate accuracy on the Base Classes Test split.
args.trainer = "CoCoOp"
args.train_batch_size = 4
args.epoch = 100
args.output_dir = "outputs/cocoop"

args.subsample_classes = "base"
args.eval_only = False
cocoop_base_acc = main(args)
```

```
Loading trainer: CoCoOp
Loading dataset: EuroSAT
Reading split from /content/ProMetaR/data/eurosat/split_zhou_EuroSAT.json
Loading preprocessed few-shot data from /content/ProMetaR/data/eurosat/split_fewshot/shot_16-seed_1.pkl
SUBSAMPLE BASE CLASSES!
Building transform_train
+ random resized crop (size=(224, 224), scale=(0.08, 1.0))
+ random flip
+ to torch tensor of range [0, 1]
+ normalization (mean=[0.48145466, 0.4578275, 0.40821073], std=[0.26862954, 0.26130258, 0.27577711])
Building transform_test
+ resize the smaller edge to 224
+ 224x224 center crop
+ to torch tensor of range [0, 1]
+ normalization (mean=[0.48145466, 0.4578275, 0.40821073], std=[0.26862954, 0.26130258, 0.27577711])
---------  -------
Dataset    EuroSAT
# classes  5
# train_x  80
# val      20
# test     4,200
---------  -------
Loading CLIP (backbone: ViT-B/16)
/usr/local/lib/python3.10/dist-packages/torch/utils/data/dataloader.py:617: UserWarning: This DataLoader will create 8 worker processes in t
  warnings.warn(
Building custom CLIP
Initial context: "a photo of a"
Number of context words (tokens): 4
Turning off gradients in both the image and the text encoder
Parameters to be updated: {'prompt_learner.meta_net.linear2.bias', 'prompt_learner.meta_net.linear2.weight', 'prompt_learner.ctx', 'prompt_l
/usr/local/lib/python3.10/dist-packages/torch/optim/lr_scheduler.py:62: UserWarning: The verbose parameter is deprecated. Please use get_las
  warnings.warn(
/content/ProMetaR/dassl/utils/torchtools.py:102: FutureWarning: You are using `torch.load` with `weights_only=False` (the current default va
  checkpoint = torch.load(fpath, map_location=map_location)
Loading evaluator: Classification
Found checkpoint at outputs/cocoop (will resume training)
Loading checkpoint from "outputs/cocoop/prompt_learner/model.pth.tar-100"
Loaded model weights
Loaded optimizer
Loaded scheduler
Previous epoch: 100
Finish training
Deploy the last-epoch model
Evaluate on the *test* set
100%|██████████| 42/42 [01:05<00:00,  1.56s/it]=> result
* total: 4,200
* correct: 3,813
```

```
      * accuracy: 90.8%
      * error: 9.2%
      * macro_f1: 90.9%
      Elapsed: 0:01:06
```

```
# Accuracy on the New Classes.
args.model_dir = "outputs/cocoop"
args.output_dir = "outputs/cocoop/new_classes"
args.subsample_classes = "new"
args.load_epoch = 100
args.eval_only = True
cocoop_novel_acc = main(args)
```

```
Loading trainer: CoCoOp
Loading dataset: EuroSAT
Reading split from /content/ProMetaR/data/eurosat/split_zhou_EuroSAT.json
Loading preprocessed few-shot data from /content/ProMetaR/data/eurosat/split_fewshot/shot_16-seed_1.pkl
SUBSAMPLE NEW CLASSES!
Building transform_train
+ random resized crop (size=(224, 224), scale=(0.08, 1.0))
+ random flip
+ to torch tensor of range [0, 1]
+ normalization (mean=[0.48145466, 0.4578275, 0.40821073], std=[0.26862954, 0.26130258, 0.27577711])
Building transform_test
+ resize the smaller edge to 224
+ 224x224 center crop
+ to torch tensor of range [0, 1]
+ normalization (mean=[0.48145466, 0.4578275, 0.40821073], std=[0.26862954, 0.26130258, 0.27577711])
---------  -------
Dataset    EuroSAT
# classes  5
# train_x  80
# val      20
# test     3,900
---------  -------
Loading CLIP (backbone: ViT-B/16)
/usr/local/lib/python3.10/dist-packages/torch/utils/data/dataloader.py:617: UserWarning: This DataLoader will create 8 worker processes in t
  warnings.warn(
/usr/local/lib/python3.10/dist-packages/torch/optim/lr_scheduler.py:62: UserWarning: The verbose parameter is deprecated. Please use get_las
  warnings.warn(
/content/ProMetaR/dassl/utils/torchtools.py:102: FutureWarning: You are using `torch.load` with `weights_only=False` (the current default va
  checkpoint = torch.load(fpath, map_location=map_location)
Building custom CLIP
Initial context: "a photo of a"
Number of context words (tokens): 4
Turning off gradients in both the image and the text encoder
Parameters to be updated: {'prompt_learner.meta_net.linear2.bias', 'prompt_learner.meta_net.linear2.weight', 'prompt_learner.ctx', 'prompt_l
Loading evaluator: Classification
Loading weights to prompt_learner from "outputs/cocoop/prompt_learner/model.pth.tar-100" (epoch = 100)
Evaluate on the *test* set
100%|██████████| 39/39 [00:59<00:00,  1.53s/it]=> result
* total: 3,900
* correct: 1,687
* accuracy: 43.3%
* error: 56.7%
* macro_f1: 39.0%
```

Q3. Analyzing the results of CoCoOp

Compare the results of CoCoOp with those of CoOp that we trained in Lab Session 4. Discuss possible reasons for the performance differences observed between CoCoOp and CoOp.

CoOpCLIP Implementation & Training

- Lab Session 4의 CoOpCLIP Implementation & Training 관련 코드 사용

```
class CoOpPromptLearner(nn.Module):
    def __init__(self, cfg, classnames, clip_model):
        super().__init__()
        n_cls = len(classnames)
        n_ctx = cfg.TRAINER.COOP.N_CTX
        ctx_init = cfg.TRAINER.COOP.CTX_INIT
        dtype = clip_model.dtype
```

```
        ctx_dim = clip_model.ln_final.weight.shape[0]
        clip_imsize = clip_model.visual.input_resolution
        cfg_imsize = cfg.INPUT.SIZE[0]
        assert cfg_imsize == clip_imsize, f"cfg_imsize ({cfg_imsize}) must equal to clip_imsize ({clip_imsize})"

        ### Learnable Prompts Initialization ###
        if ctx_init:
            # use given words to initialize context vectors
            ctx_init = ctx_init.replace("_", " ")
            n_ctx = len(ctx_init.split(" "))
            prompt = clip.tokenize(ctx_init)
            with torch.no_grad():
                embedding = clip_model.token_embedding(prompt).type(dtype)
            ctx_vectors = embedding[0, 1 : 1 + n_ctx, :]
            prompt_prefix = ctx_init
        else:
            # random initialization
            if cfg.TRAINER.COOP.CSC:
                print("Initializing class-specific contexts")
                ctx_vectors = torch.empty(n_cls, n_ctx, ctx_dim, dtype=dtype)
            else:
                print("Initializing a generic context")
                ctx_vectors = torch.empty(n_ctx, ctx_dim, dtype=dtype)
            nn.init.normal_(ctx_vectors, std=0.02)
            prompt_prefix = " ".join(["X"] * n_ctx)
        print(f'Initial context: "{prompt_prefix}"')
        print(f"Number of context words (tokens): {n_ctx}")
        self.ctx = nn.Parameter(ctx_vectors)  # Wrap the initialized prompts above as parameters to make them trainable.

        ### Tokenize ###
        classnames = [name.replace("_", " ") for name in classnames]  # 예) "Forest"
        name_lens = [len(_tokenizer.encode(name)) for name in classnames]
        prompts = [prompt_prefix + " " + name + "." for name in classnames] # 예) "A photo of Forest."
        tokenized_prompts = torch.cat([clip.tokenize(p) for p in prompts]) # 예) [49406, 320, 1125, 539...]
        ################

        with torch.no_grad():
            embedding = clip_model.token_embedding(tokenized_prompts).type(dtype)
        # These token vectors will be saved when in save_model(),
        # but they should be ignored in load_model() as we want to use
        # those computed using the current class names
        self.register_buffer("token_prefix", embedding[:, :1, :])  # SOS (문장의 시작을 알려주는 토큰)
        self.register_buffer("token_suffix", embedding[:, 1 + n_ctx :, :])  # CLS, EOS (문장의 끝을 알려주는 토큰)
        self.n_cls = n_cls
        self.n_ctx = n_ctx
        self.tokenized_prompts = tokenized_prompts  # torch.Tensor
        self.name_lens = name_lens

    def construct_prompts(self, ctx, prefix, suffix, label=None):
        # dim0 is either batch_size (during training) or n_cls (during testing)
        # ctx: context tokens, with shape of (dim0, n_ctx, ctx_dim)
        # prefix: the sos token, with shape of (n_cls, 1, ctx_dim)
        # suffix: remaining tokens, with shape of (n_cls, *, ctx_dim)
        if label is not None:
            prefix = prefix[label]
            suffix = suffix[label]
        prompts = torch.cat(
            [
                prefix,  # (dim0, 1, dim)
                ctx,  # (dim0, n_ctx, dim)
                suffix,  # (dim0, *, dim)
            ],
            dim=1,
        )
        return prompts

    def forward(self):
        ctx = self.ctx
        if ctx.dim() == 2:
            ctx = ctx.unsqueeze(0).expand(self.n_cls, -1, -1)
        prefix = self.token_prefix
        suffix = self.token_suffix
        prompts = self.construct_prompts(ctx, prefix, suffix) #[시작토큰, Input prompts,끝 토큰]
        return prompts


class CoOpCustomCLIP(nn.Module):
    def __init__(self, cfg, classnames, clip_model):
        super().__init__()
```

```
        self.prompt_learner = CoOpPromptLearner(cfg, classnames, clip_model)
        self.tokenized_prompts = self.prompt_learner.tokenized_prompts
        self.image_encoder = clip_model.visual
        self.text_encoder = TextEncoder(clip_model)
        self.logit_scale = clip_model.logit_scale
        self.dtype = clip_model.dtype

    def forward(self, image):
        image_features = self.image_encoder(image.type(self.dtype))

        prompts = self.prompt_learner()
        tokenized_prompts = self.tokenized_prompts
        text_features = self.text_encoder(prompts, tokenized_prompts)

        image_features = image_features / image_features.norm(dim=-1, keepdim=True)
        text_features = text_features / text_features.norm(dim=-1, keepdim=True)

        logit_scale = self.logit_scale.exp()
        logits = logit_scale * image_features @ text_features.t()

        return logits


parser = argparse.ArgumentParser()
parser.add_argument("--root", type=str, default="data/", help="path to dataset")
parser.add_argument("--output-dir", type=str, default="outputs/cocoop3", help="output directory")
parser.add_argument(
    "--seed", type=int, default=1, help="only positive value enables a fixed seed"
)
parser.add_argument(
    "--config-file", type=str, default="configs/trainers/ProMetaR/vit_b16_c2_ep10_batch4_4+4ctx.yaml", help="path to config file"
)
parser.add_argument(
    "--dataset-config-file",
    type=str,
    default="configs/datasets/eurosat.yaml",
    help="path to config file for dataset setup",
)
parser.add_argument("--trainer", type=str, default="CoOp", help="name of trainer")
parser.add_argument("--eval-only", action="store_true", help="evaluation only")
parser.add_argument(
    "--model-dir",
    type=str,
    default="",
    help="load model from this directory for eval-only mode",
)
parser.add_argument("--train-batch-size", type=int, default=4)
parser.add_argument("--epoch", type=int, default=10)
parser.add_argument("--subsample-classes", type=str, default="base")
parser.add_argument(
    "--load-epoch", type=int, default=0, help="load model weights at this epoch for evaluation"
)
args = parser.parse_args([])
```

```
@TRAINER_REGISTRY.register(force=True)
class CoOp(TrainerX):
    """Context Optimization (CoOp).

    Learning to Prompt for Vision-Language Models
    https://arxiv.org/abs/2109.01134
    """

    def check_cfg(self, cfg):
        assert cfg.TRAINER.COOP.PREC in ["fp16", "fp32", "amp"]

    def build_model(self):
        cfg = self.cfg
        classnames = self.dm.dataset.classnames

        print(f"Loading CLIP (backbone: {cfg.MODEL.BACKBONE.NAME})")
        clip_model = load_clip_to_cpu(cfg)

        if cfg.TRAINER.COOP.PREC == "fp32" or cfg.TRAINER.COOP.PREC == "amp":
            # CLIP's default precision is fp16
            clip_model.float()

        print("Building custom CLIP")
        self.model = CoOpCustomCLIP(cfg, classnames, clip_model)
```

```
        print("Turning off gradients in both the image and the text encoder")
        for name, param in self.model.named_parameters():
            if "prompt_learner" not in name:
                param.requires_grad_(False)

        if cfg.MODEL.INIT_WEIGHTS:
            load_pretrained_weights(self.model.prompt_learner, cfg.MODEL.INIT_WEIGHTS)

        self.model.to(self.device)
        # NOTE: only give prompt_learner to the optimizer
        self.optim = build_optimizer(self.model.prompt_learner, cfg.OPTIM)
        self.sched = build_lr_scheduler(self.optim, cfg.OPTIM)
        self.register_model("prompt_learner", self.model.prompt_learner, self.optim, self.sched)

        self.scaler = GradScaler() if cfg.TRAINER.COOP.PREC == "amp" else None

        # Note that multi-gpu training could be slow because CLIP's size is
        # big, which slows down the copy operation in DataParallel
        device_count = torch.cuda.device_count()
        if device_count > 1:
            print(f"Multiple GPUs detected (n_gpus={device_count}), use all of them!")
            self.model = nn.DataParallel(self.model)

    def before_train(self):
        directory = self.cfg.OUTPUT_DIR
        if self.cfg.RESUME:
            directory = self.cfg.RESUME
        self.start_epoch = self.resume_model_if_exist(directory)

        # Remember the starting time (for computing the elapsed time)
        self.time_start = time.time()

    def forward_backward(self, batch):
        image, label = self.parse_batch_train(batch)

        prec = self.cfg.TRAINER.COOP.PREC
        output = self.model(image)      # Input image 모델 통과
        loss = F.cross_entropy(output, label)  # Loss 선언
        self.model_backward_and_update(loss)  # Backward 및 모델 parameter 업데이트

        loss_summary = {
            "loss": loss.item(),
            "acc": compute_accuracy(output, label)[0].item(),
        }

        if (self.batch_idx + 1) == self.num_batches:
            self.update_lr()

        return loss_summary

    def parse_batch_train(self, batch):
        input = batch["img"]
        label = batch["label"]
        input = input.to(self.device)
        label = label.to(self.device)
        return input, label

    def load_model(self, directory, epoch=None):
        if not directory:
            print("Note that load_model() is skipped as no pretrained model is given")
            return

        names = self.get_model_names()

        # By default, the best model is loaded
        model_file = "model-best.pth.tar"

        if epoch is not None:
            model_file = "model.pth.tar-" + str(epoch)

        for name in names:
            model_path = osp.join(directory, name, model_file)

            if not osp.exists(model_path):
                raise FileNotFoundError('Model not found at "{}"'.format(model_path))

            checkpoint = load_checkpoint(model_path)
            state_dict = checkpoint["state_dict"]
            epoch = checkpoint["epoch"]
```

```
        # Ignore fixed token vectors
        if "token_prefix" in state_dict:
            del state_dict["token_prefix"]

        if "token_suffix" in state_dict:
            del state_dict["token_suffix"]

        print("Loading weights to {} " 'from "{}" (epoch = {})'.format(name, model_path, epoch))
        # set strict=False
        self._models[name].load_state_dict(state_dict, strict=False)

def after_train(self):
  print("Finish training")

  do_test = not self.cfg.TEST.NO_TEST
  if do_test:
      if self.cfg.TEST.FINAL_MODEL == "best_val":
          print("Deploy the model with the best val performance")
          self.load_model(self.output_dir)
      else:
          print("Deploy the last-epoch model")
      acc = self.test()

  # Show elapsed time
  elapsed = round(time.time() - self.time_start)
  elapsed = str(datetime.timedelta(seconds=elapsed))
  print(f"Elapsed: {elapsed}")

  # Close writer
  self.close_writer()
  return acc

    def train(self):
        """Generic training loops."""
        self.before_train()
        for self.epoch in range(self.start_epoch, self.max_epoch):
            self.before_epoch()
            self.run_epoch()
            self.after_epoch()
        acc = self.after_train()
        return acc


def main(args):
    cfg = setup_cfg(args)
    if cfg.SEED >= 0:
        set_random_seed(cfg.SEED)

    if torch.cuda.is_available() and cfg.USE_CUDA:
        torch.backends.cudnn.benchmark = True

    trainer = build_trainer(cfg)
    if args.eval_only:
        trainer.load_model(args.model_dir, epoch=args.load_epoch)
        acc = trainer.test()
        return acc

    acc = trainer.train()
    return acc


# Train on the Base Classes Train split and evaluate accuracy on the Base Classes Test split.
args.trainer = "CoOp"
args.train_batch_size = 4
args.epoch = 100
args.output_dir = "outputs/coop"

args.subsample_classes = "base"
coop_base_acc = main(args)
```

```
Loading trainer: CoOp
Loading dataset: EuroSAT
Reading split from /content/ProMetaR/data/eurosat/split_zhou_EuroSAT.json
Loading preprocessed few-shot data from /content/ProMetaR/data/eurosat/split_fewshot/shot_16-seed_1.pkl
SUBSAMPLE BASE CLASSES!
Building transform_train
+ random resized crop (size=(224, 224), scale=(0.08, 1.0))
+ random flip
+ to torch tensor of range [0, 1]
+ normalization (mean=[0.48145466, 0.4578275, 0.40821073], std=[0.26862954, 0.26130258, 0.27577711])
```

```
Building transform_test
+ resize the smaller edge to 224
+ 224x224 center crop
+ to torch tensor of range [0, 1]
+ normalization (mean=[0.48145466, 0.4578275, 0.40821073], std=[0.26862954, 0.26130258, 0.27577711])
---------  -------
Dataset    EuroSAT
# classes  5
# train_x  80
# val      20
# test     4,200
---------  -------
Loading CLIP (backbone: ViT-B/16)
/usr/local/lib/python3.10/dist-packages/torch/utils/data/dataloader.py:617: UserWarning: This DataLoader will create 8 worker processes in t
  warnings.warn(
/usr/local/lib/python3.10/dist-packages/torch/optim/lr_scheduler.py:62: UserWarning: The verbose parameter is deprecated. Please use get_las
  warnings.warn(
/content/ProMetaR/dassl/utils/torchtools.py:102: FutureWarning: You are using `torch.load` with `weights_only=False` (the current default va
  checkpoint = torch.load(fpath, map_location=map_location)
Building custom CLIP
Initializing a generic context
Initial context: "X X X X X X X X X X X X X X X X"
Number of context words (tokens): 16
Turning off gradients in both the image and the text encoder
Loading evaluator: Classification
Found checkpoint at outputs/coop (will resume training)
Loading checkpoint from "outputs/coop/prompt_learner/model.pth.tar-100"
Loaded model weights
Loaded optimizer
Loaded scheduler
Previous epoch: 100
Finish training
Deploy the last-epoch model
Evaluate on the *test* set
100%|██████████| 42/42 [00:17<00:00,  2.37it/s]=> result
* total: 4,200
* correct: 3,839
* accuracy: 91.4%
* error: 8.6%
* macro_f1: 91.5%
Elapsed: 0:00:18
```

```
# Accuracy on the New Classes.
args.model_dir = "outputs/coop"
args.output_dir = "outputs/coop/new_classes"
args.subsample_classes = "new"
args.load_epoch = 100
args.eval_only = True
coop_novel_acc = main(args)
```

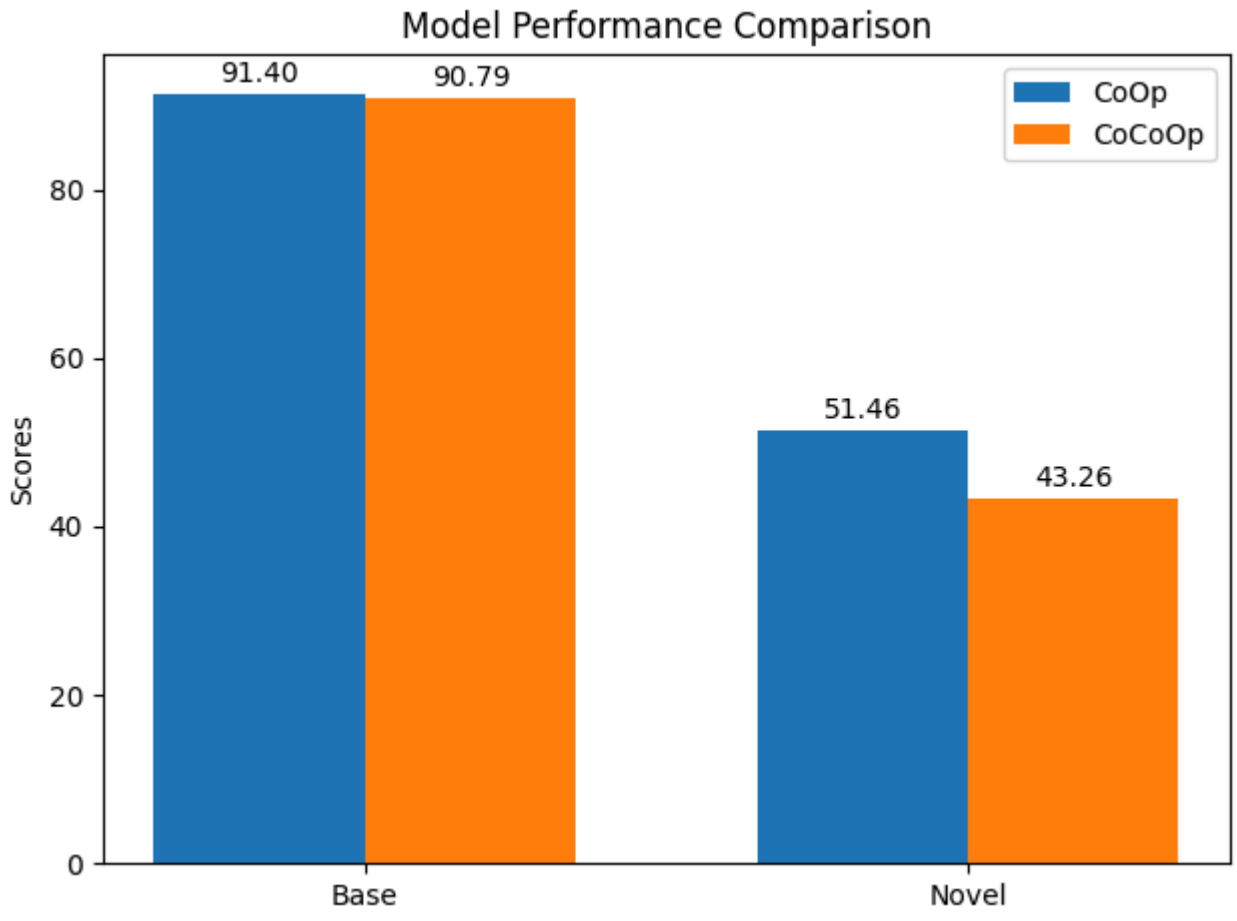
```
Loading trainer: CoOp
Loading dataset: EuroSAT
Reading split from /content/ProMetaR/data/eurosat/split_zhou_EuroSAT.json
Loading preprocessed few-shot data from /content/ProMetaR/data/eurosat/split_fewshot/shot_16-seed_1.pkl
SUBSAMPLE NEW CLASSES!
Building transform_train
+ random resized crop (size=(224, 224), scale=(0.08, 1.0))
+ random flip
+ to torch tensor of range [0, 1]
+ normalization (mean=[0.48145466, 0.4578275, 0.40821073], std=[0.26862954, 0.26130258, 0.27577711])
Building transform_test
+ resize the smaller edge to 224
+ 224x224 center crop
+ to torch tensor of range [0, 1]
+ normalization (mean=[0.48145466, 0.4578275, 0.40821073], std=[0.26862954, 0.26130258, 0.27577711])
---------  -------
Dataset    EuroSAT
# classes  5
# train_x  80
# val      20
# test     3,900
---------  -------
Loading CLIP (backbone: ViT-B/16)
/usr/local/lib/python3.10/dist-packages/torch/utils/data/dataloader.py:617: UserWarning: This DataLoader will create 8 worker processes in t
  warnings.warn(
/usr/local/lib/python3.10/dist-packages/torch/optim/lr_scheduler.py:62: UserWarning: The verbose parameter is deprecated. Please use get_las
  warnings.warn(
/content/ProMetaR/dassl/utils/torchtools.py:102: FutureWarning: You are using `torch.load` with `weights_only=False` (the current default va
  checkpoint = torch.load(fpath, map_location=map_location)
Building custom CLIP
Initializing a generic context
Initial context: "X X X X X X X X X X X X X X X X"
Number of context words (tokens): 16
```

```
Turning off gradients in both the image and the text encoder
Loading evaluator: Classification
Loading weights to prompt_learner from "outputs/coop/prompt_learner/model.pth.tar-100" (epoch = 100)
Evaluate on the *test* set
100%|██████████| 39/39 [00:16<00:00,  2.33it/s]=> result
* total: 3,900
* correct: 2,007
* accuracy: 51.5%
* error: 48.5%
* macro_f1: 45.6%
```

CoOp와 CoCoOp의 모델 성능 비교 그래프

- Lab Session 4의 Model Performance Comparison을 위해 사용된 Visualization 관련 코드 사용

```
import matplotlib.pyplot as plt
import numpy as np

# 메트릭 데이터
metrics = ['Base', 'Novel']

coop_acc_list = [coop_base_acc, coop_novel_acc]
cocoop_acc_list = [cocoop_base_acc, cocoop_novel_acc]


# 막대 너비
bar_width = 0.35

# X축 위치 설정
index = np.arange(len(metrics))

# bar plot 생성
fig, ax = plt.subplots()

bar1 = ax.bar(index, coop_acc_list, bar_width, label='CoOp')
bar2 = ax.bar(index + bar_width, cocoop_acc_list, bar_width, label='CoCoOp')

# 제목과 레이블 설정
ax.set_ylabel('Scores')
ax.set_title('Model Performance Comparison')
ax.set_xticks(index + bar_width / 2)
ax.set_xticklabels(metrics)
ax.legend()

# 막대에 값 표시
def add_value_labels(bars):
    for bar in bars:
        height = bar.get_height()
        ax.annotate(f'{height:.2f}', xy=(bar.get_x() + bar.get_width() / 2, height),
                    xytext=(0, 2),  # 2 points vertical offset
                    textcoords='offset points',
                    ha='center', va='bottom')

add_value_labels(bar1)
add_value_labels(bar2)

# 그래프 출력
plt.tight_layout()
plt.show()
```



CoOp와 CoCoOp 사이의 성능 차이가 발생하는 possible reasons

- CoOp와 CoCoOp의 모델 성능 비교 그래프를 보면 Base 클래스와 Novel 클래스에 대해 모두 CoOp이 더 나은 성능을 보인다.
- Base 클래스는 훈련 데이터에 포함된 이미 학습한 클래스이다. 따라서 Base 클래스에서의 정확도는 CoOp과 CoCoOp 모두 잘 동작해야한다. 그렇기 때문에, 그래프 상에서도 Base 클래스에 대해 CoOp는 91.40, CoCoOp는 90.79로 미세한 차이가 있지만 두 모델 모두 높은 성능이 나타나는 것을 보여주고 있다.
- Base 클래스에서 CoOp가 CoCoOp에 비해 미세하게 높은 성능을 가지는 이유는 CoOp는 고정된 컨텍스트 벡터를 사용하여 Base 클래스에 대한 예측을 수행하므로, 기존에 훈련된 특성을 그대로 활용할 수 있다. 이로 인해 Base 클래스에 대한 성능이 상대적으로 높을 수 있다.
- Novel 클래스는 훈련 데이터에 포함되지 않은 새로운 클래스이다. 모델이 기존의 지식을 새로운 클래스에 적응시키는 과정이 중요하다. 여기에서 두 모델의 성능 차이가 더욱 두드러질 수 있다.
- CoCoOp는 동적 학습을 통해 새로운 클래스에 대한 적응이 가능하므로, 새로운 클래스에서의 성능이 더 높을 가능성이 있다. 하지만, 과적합이나 학습의 불안정성으로 인해 성능이 예상과 달리 낮아질 수 있다.
- 그래프를 보면 Novel 클래스에 대해서도 CoCoOp가 CoOp에 비해 낮은 성능을 보이는데, 과적합, 학습의 불안정성, 모델 복잡성 등의 이유로 CoCoOp이 새로운 클래스에서 기대한 만큼 잘 동작하지 않았을 가능성이 크다.