```
from google.colab import drive
drive.mount('/content/drive', force_remount=True)
```

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

```
!pip -q install timm tqdm

```

## 데이터셋 구축

train/val 데이터 분할

```
# === 설정 ===
from pathlib import Path
import shutil, random

from pathlib import Path
import shutil, random

SRC = Path("/content/drive/MyDrive/gayoung/ba/label_space_data/dataset_trainval")
DST_T = Path("/content/drive/MyDrive/gayoung/ba/label_space_data/dataset_train")
DST_V = Path("/content/drive/MyDrive/gayoung/ba/label_space_data/dataset_val")
    # 출력(val)

TRAIN_RATIO = 0.8
RANDOM_SEED = 42                   # 재현성

# 파일 확장자(필요시 수정)
IMG_EXTS = {".jpg", ".jpeg", ".png", ".bmp", ".webp"}
LBL_EXT  = ".txt"                  # YOLO 형식 가정

random.seed(RANDOM_SEED)

def is_hidden(p: Path) -> bool:
    return p.name.startswith(".") or p.name.startswith("._")

def ensure_dir(p: Path):
    p.mkdir(parents=True, exist_ok=True)

# 존재하는 서브폴더만 사용(images/labels/preview 중 실제 있는 것만)
SUBS = [d.name for d in SRC.iterdir() if d.is_dir() and d.name in {"images","labels","preview"}]
print("대상 서브폴더:", SUBS)

# 클래스 목록은 images 기준으로 얻음
classes = sorted([d.name for d in (SRC/"images").iterdir() if d.is_dir() and not is_hidden(d)])
print("클래스:", classes)

# 통계
stats = {c: {"train":0, "val":0} for c in classes}
total_train = total_val = 0

for cls in classes:
    img_cls_dir = SRC/"images"/cls
    lbl_cls_dir = SRC/"labels"/cls

    # 이미지 파일 수집(숨김/리소스 파일 제외)
    imgs = [p for p in img_cls_dir.iterdir() if p.is_file() and not is_hidden(p) and p.suffix.lower() in IMG_EXTS]
    # 라벨이 존재하는 이미지만 남김(베이스네임 매칭)
    good = []
    for img in imgs:
        base = img.stem
        lbl  = lbl_cls_dir/(base + LBL_EXT)
        if lbl.exists() and not is_hidden(lbl):
            good.append((img, lbl))

    random.shuffle(good)
    k = int(len(good) * TRAIN_RATIO)
    train_pairs = good[:k]
    val_pairs   = good[k:]

    # 복사 함수
    def copy_pairs(pairs, split_root):
        img_out = split_root/"images"/cls
        lbl_out = split_root/"labels"/cls
        ensure_dir(img_out); ensure_dir(lbl_out)
        for img, lbl in pairs:
            shutil.copy2(img, img_out/img.name)
            shutil.copy2(lbl, lbl_out/lbl.name)
        return len(pairs)

    stats[cls]["train"] = copy_pairs(train_pairs, DST_T)
    stats[cls]["val"]   = copy_pairs(val_pairs,   DST_V)
    total_train += stats[cls]["train"]
    total_val   += stats[cls]["val"]

# preview 폴더가 있으면 동일 비율로 파일만 분할(라벨 없음)
if "preview" in SUBS:
    for cls in sorted([d.name for d in (SRC/"preview").iterdir() if d.is_dir() and not is_hidden(d)]):
        prev_cls_dir = SRC/"preview"/cls
        files = [p for p in prev_cls_dir.iterdir() if p.is_file() and not is_hidden(p)]
        random.shuffle(files)
        k = int(len(files) * TRAIN_RATIO)
        train_f, val_f = files[:k], files[k:]
        for dst_root, lst in [(DST_T, train_f), (DST_V, val_f)]:
            out_dir = dst_root/"preview"/cls
            ensure_dir(out_dir)
            for f in lst:
                shutil.copy2(f, out_dir/f.name)

# 결과 요약 출력
print("\n=== 분할 요약 ===")
for cls in classes:
    print(f"{cls:>20}: train {stats[cls]['train']:4d} | val {stats[cls]['val']:4d}")
print(f"\n총계 → train: {total_train}  /  val: {total_val}")
print("✅ 완료: /content/gayoung/ba/label_space_data/dataset_train & dataset_val")
```

```
대상 서브폴더: ['images', 'preview', 'labels']
클래스: ['DANCE_STUDIO', 'MAKER_SPACE', 'MUSIC_PRACTICE_ROOM', 'SMALL_THEATER', 'STUDY_ROOM']

=== 분할 요약 ===
        DANCE_STUDIO: train    8 | val    2
         MAKER_SPACE: train   24 | val    7
 MUSIC_PRACTICE_ROOM: train   30 | val    8
       SMALL_THEATER: train   20 | val    6
          STUDY_ROOM: train   33 | val    9

총계 → train: 115  /  val: 32
✅ 완료: /content/gayoung/ba/label_space_data/dataset_train & dataset_val
```

## (train/val) Before/After + GT 마스크 생성

1. 목표: 실제 환경과 유사한 다양한 변화(가림/블러/픽셀화/인페인트/이동)를 자동 적용해, (before, after, mask) 쌍을 일괄 생성
2. 마스크 규칙: 0=배경, 255=변경 영역
3. 활용: 변화 감지(Change Detection), 전/후 비교, 분할(Segmentation) 학습 및 벤치마킹

```
import os, json, random, cv2, numpy as np
from pathlib import Path

random.seed(42)

# ====== 경로 설정 ======
BASE = Path("/content/drive/MyDrive/gayoung/ba/label_space_data")
IN_SPLITS = ["dataset_train","dataset_val"]  # 둘 다 처리
OUT = Path("/content/drive/MyDrive/gayoung/ba/pairs_out_cd")   # 결과

# ====== 파라미터 ======
IMG_EXTS = {".jpg",".jpeg",".png",".bmp",".webp"}
YOLO_LBL_EXT = ".txt"
APPLY_MASK_PROB = 0.85       # 이 확률로 변경 적용(낮추면 '변화 없음' 샘플도 섞임)
MASK_MODE_SET = ["black","inpaint","rect","blur","pixel"]  # 가림 방식 후보
RECT_JITTER = 0.12           # bbox 주변 랜덤 여유
PARTIAL_KEEP_PROB = 0.25     # 변경 영역 일부는 남김(부분 가림)
MIN_BOX_AREA = 20*20         # 너무 작은 박스는 생략
MAX_MOVED_TRIES = 10         # 이동 시도 횟수(경계 밖 방지)

def is_hidden(p: Path): return p.name.startswith(".") or p.name.startswith("._")

def ensure_dir(p: Path): p.mkdir(parents=True, exist_ok=True)

def read_yolo(txt_path: Path):
    boxes = []
    if not txt_path.exists(): return boxes
    for line in open(txt_path,"r"):
        ps = line.strip().split()
        if len(ps) < 5: continue
        # cls cx cy w h  (normalized)
        cls, cx, cy, w, h = ps[:5]
        try:
            cx, cy, w, h = map(float, (cx, cy, w, h))
            boxes.append((cx,cy,w,h))
        except:
            continue
    return boxes

def yolo_to_xywh(box, W, H):
    cx,cy,w,h = box
    bw, bh = int(w*W), int(h*H)
    x = int((cx - w/2)*W); y = int((cy - h/2)*H)
    x = max(0,x); y = max(0,y)
    x2 = min(W-1, x+bw); y2 = min(H-1, y+bh)
    return x,y, max(2,x2-x), max(2,y2-y)

def jitter_rect(x,y,w,h,W,H,rate):
    jx, jy = int(w*rate), int(h*rate)
    x = max(0, min(W-1, x + random.randint(-jx, jx)))
    y = max(0, min(H-1, y + random.randint(-jy, jy)))
    w = max(2, w + random.randint(-jx, jx))
    h = max(2, h + random.randint(-jy, jy))
    x2 = max(0, min(W-1, x+w)); y2 = max(0, min(H-1, y+h))
    return x, y, x2-x, y2-y

def non_overlapping(new_box, existing, min_iou=0.05):
    # new_box, existing: [x,y,w,h] in pixels
    def iou(a, b):
        ax1,ay1,aw,ah = a; ax2,ay2 = ax1+aw, ay1+ah
        bx1,by1,bw,bh = b; bx2,by2 = bx1+bw, by1+bh
        ix1, iy1 = max(ax1,bx1), max(ay1,by1)
        ix2, iy2 = min(ax2,bx2), min(ay2,by2)
        iw, ih = max(0, ix2-ix1), max(0, iy2-iy1)
        inter = iw*ih
        union = aw*ah + bw*bh - inter + 1e-6
        return inter/union
    return all(iou(new_box, b) <= min_iou for b in existing)

def inpaint_rect(img, x,y,w,h):
    mask = np.zeros(img.shape[:2], np.uint8)
    cv2.rectangle(mask,(x,y),(x+w,y+h),255,-1)
    return cv2.inpaint(img, mask, 3, cv2.INPAINT_TELEA)

def blur_rect(img, x,y,w,h):
    roi = img[y:y+h, x:x+w]
    if roi.size == 0: return img
    k = max(3, (min(w,h)//10)*2+1)
    img[y:y+h, x:x+w] = cv2.GaussianBlur(roi, (k,k), 0)
    return img

def pixelate_rect(img, x,y,w,h, factor=0.1):
    roi = img[y:y+h, x:x+w]
    if roi.size == 0: return img
    down_w, down_h = max(1,int(w*factor)), max(1,int(h*factor))
    small = cv2.resize(roi,(down_w,down_h), interpolation=cv2.INTER_LINEAR)
    img[y:y+h, x:x+w] = cv2.resize(small,(w,h), interpolation=cv2.INTER_NEAREST)
    return img

def paste_move(img, x,y,w,h, W,H, existing):
    """ 박스를 잘라서 새 위치로 '이동' (라벨용 변경 마스크엔 원위치와 새 위치 모두 반영) """
    src = img[y:y+h, x:x+w].copy()
    tries = 0
    while tries < MAX_MOVED_TRIES:
        nx = random.randint(0, max(0,W-w)); ny = random.randint(0, max(0,H-h))
        cand = [nx,ny,w,h]
        if non_overlapping(cand, existing, min_iou=0.1):
            img[ny:ny+h, nx:nx+w] = src
            # 원 위치는 검정으로 지우기
            img[y:y+h, x:x+w] = 0
            return img, cand
        tries += 1
    return img, None

def apply_change(after, change_mask, box_xywh, W,H):
    """ box를 약간 흔들고, 다양한 방식으로 가림/이동. change_mask에 변경 영역 반영 """
    x,y,w,h = box_xywh
    # 너무 작은 박스는 생략
    if w*h < MIN_BOX_AREA: return after, change_mask, None
    # 살짝 여유/흔들기
    x,y,w,h = jitter_rect(x,y,w,h,W,H, RECT_JITTER)

    mode = random.choice(MASK_MODE_SET + ["move","move"])  # 이동 가중치 조금 높임
    moved_to = None

    if mode == "black":
        cv2.rectangle(after,(x,y),(x+w,y+h),(0,0,0),-1)
        cv2.rectangle(change_mask,(x,y),(x+w,y+h),255,-1)
    elif mode == "rect":
        patch = np.random.randint(0, 30, (h,w,3), dtype=np.uint8)
        after[y:y+h, x:x+w] = patch
        cv2.rectangle(change_mask,(x,y),(x+w,y+h),255,-1)
    elif mode == "inpaint":
        after[:] = inpaint_rect(after, x,y,w,h)
        cv2.rectangle(change_mask,(x,y),(x+w,y+h),255,-1)
    elif mode == "blur":
        after[:] = blur_rect(after, x,y,w,h)
        cv2.rectangle(change_mask,(x,y),(x+w,y+h),255,-1)
    elif mode == "pixel":
        after[:] = pixelate_rect(after, x,y,w,h, factor=0.15)
        cv2.rectangle(change_mask,(x,y),(x+w,y+h),255,-1)
    elif mode == "move":
        prev = [x,y,w,h]
        after[:], moved_to = paste_move(after, x,y,w,h, W,H, existing=[])
        # 마스크: 원 위치 + 새 위치
        cv2.rectangle(change_mask,(x,y),(x+w,y+h),255,-1)
        if moved_to is not None:
            nx,ny,nw,nh = moved_to
            cv2.rectangle(change_mask,(nx,ny),(nx+nw,ny+nh),255,-1)

    # 변경영역 일부만 남기기(컨투어 단위로 삭제)
    if random.random() < PARTIAL_KEEP_PROB:
        cnts,_ = cv2.findContours(change_mask, cv2.RETR_EXTERNAL, cv2.CHAIN_APPROX_SIMPLE)
        for c in cnts:
            if cv2.contourArea(c) < MIN_BOX_AREA: continue
            if random.random() < 0.5:
                cv2.drawContours(change_mask, [c], -1, 0, -1)

    return after, change_mask, moved_to

def process_split(split_name: str):
    in_root = BASE / split_name
    img_root = in_root / "images"
    lbl_root = in_root / "labels"

    out_b = OUT / split_name.replace("dataset_","") / "before_images"
    out_a = OUT / split_name.replace("dataset_","") / "after_images"
    out_y = OUT / split_name.replace("dataset_","") / "labels"
    for d in [out_b, out_a, out_y]: ensure_dir(d)

    meta = []
    classes = [d.name for d in img_root.iterdir() if d.is_dir() and not is_hidden(d)]
    total_pairs = 0

    for cls in classes:
        cls_img = img_root/cls
        cls_lbl = lbl_root/cls
        files = [p for p in cls_img.iterdir() if p.is_file() and p.suffix.lower() in IMG_EXTS and not is_hidden(p)]
        for imgp in files:
            base = imgp.stem
            lblp = cls_lbl/(base + YOLO_LBL_EXT)
            if not lblp.exists():
                # 라벨이 없으면 '변경 없음' 샘플로 만들 수도 있지만 기본은 스킵
                continue

            img = cv2.imread(str(imgp), cv2.IMREAD_COLOR)
            if img is None: continue
            H,W = img.shape[:2]
            boxes = read_yolo(lblp)
            if not boxes:
                # 박스가 없으면 '변경 없음' 샘플로 추가
                after = img.copy()
                change_mask = np.zeros((H,W), np.uint8)
            else:
                after = img.copy()
                change_mask = np.zeros((H,W), np.uint8)
                if random.random() < APPLY_MASK_PROB:
                    # 일부/전부 선택해서 변경
                    chosen = []
                    for b in boxes:
                        x,y,w,h = yolo_to_xywh(b, W,H)
                        chosen.append([x,y,w,h])
                    # 랜덤하게 일부만 변경
                    k = random.randint(1, max(1, len(chosen)))
                    for (x,y,w,h) in random.sample(chosen, k=k):
                        after, change_mask, _ = apply_change(after, change_mask, [x,y,w,h], W,H)
                else:
                    # 변화 없음 샘플
                    pass

            # 파일명 충돌 방지 위해 클래스 접두사
            out_name = f"{cls}__{imgp.name}"
            cv2.imwrite(str(out_b/out_name), img)
            cv2.imwrite(str(out_a/out_name), after)
            cv2.imwrite(str(out_y/(Path(out_name).stem + ".png")), change_mask)

            meta.append({
                "split": split_name.replace("dataset_",""),
                "class": cls,
                "before": str((out_b/out_name).as_posix()),
                "after":  str((out_a/out_name).as_posix()),
                "label":  str((out_y/(Path(out_name).stem + ".png")).as_posix())
            })
            total_pairs += 1

    # 메타 저장
    ensure_dir(OUT/"meta")
    with open(OUT/"meta"/f"pairs_{split_name.replace('dataset_','')}.json","w") as f:
        json.dump(meta, f, indent=2, ensure_ascii=False)

    print(f"[{split_name}] 생성 쌍: {total_pairs}")
    return total_pairs

# 실행
ensure_dir(OUT)
tot = 0
for sp in IN_SPLITS:
    tot += process_split(sp)
print(f"[DONE] 총 생성 쌍: {tot}")
print(f"출력 루트: {OUT}")
```

```
[dataset_train] 생성 쌍: 115
[dataset_val] 생성 쌍: 32
[DONE] 총 생성 쌍: 147
출력 루트: /content/drive/MyDrive/gayoung/ba/pairs_out_cd
```

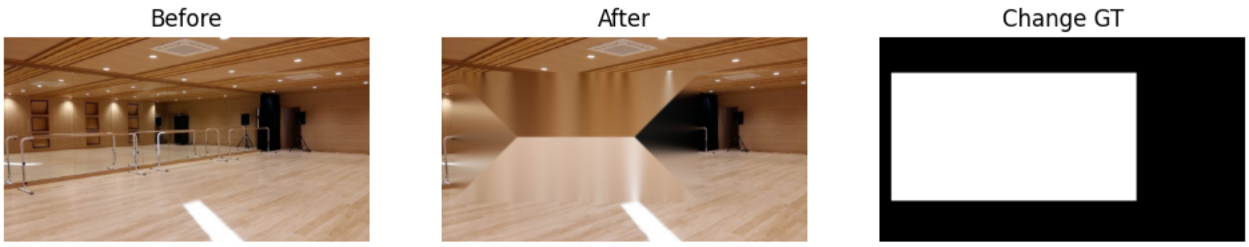
train/val 분할 결과

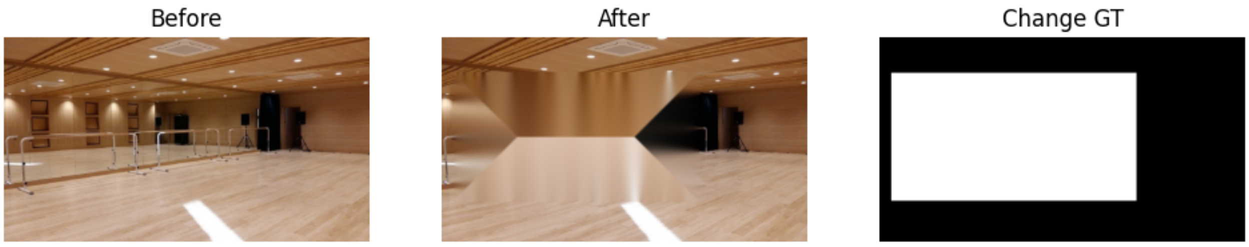
```
import os
def count_files(p):
    return sum(len(files) for _,_,files in os.walk(p))
root = "/content/drive/MyDrive/gayoung/ba/pairs_out_cd"
print("train before:", count_files(f"{root}/train/before_images"))
print("train after :", count_files(f"{root}/train/after_images"))
print("train labels:", count_files(f"{root}/train/labels"))
print("val   before:", count_files(f"{root}/val/before_images"))
print("val   after :", count_files(f"{root}/val/after_images"))
print("val   labels:", count_files(f"{root}/val/labels"))
```

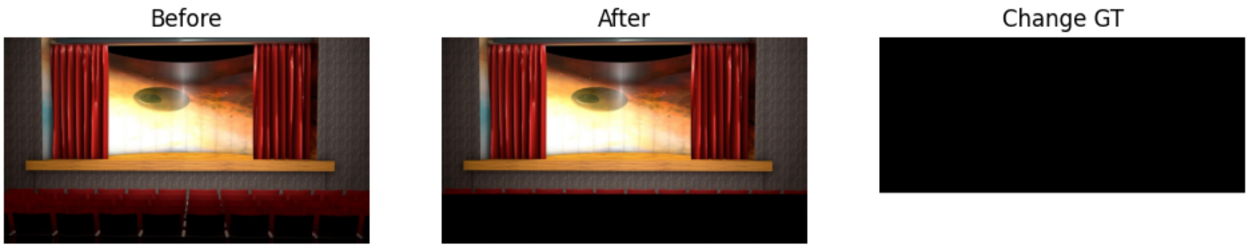
```
train before: 115
train after : 115
train labels: 115
val   before: 32
val   after : 32
val   labels: 32
```

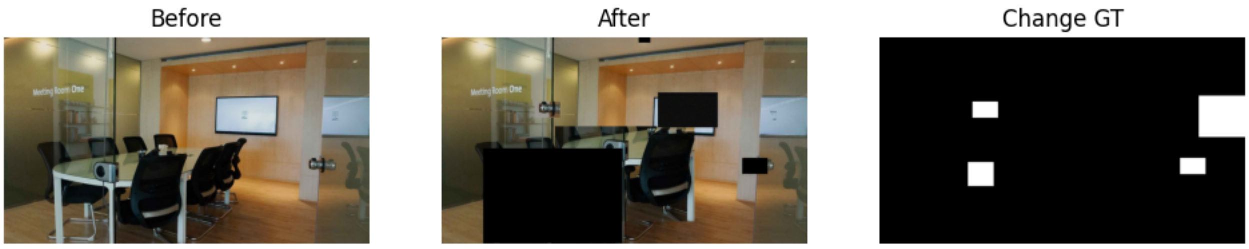
**(train/val) before, aftert, change GT mask 예시**

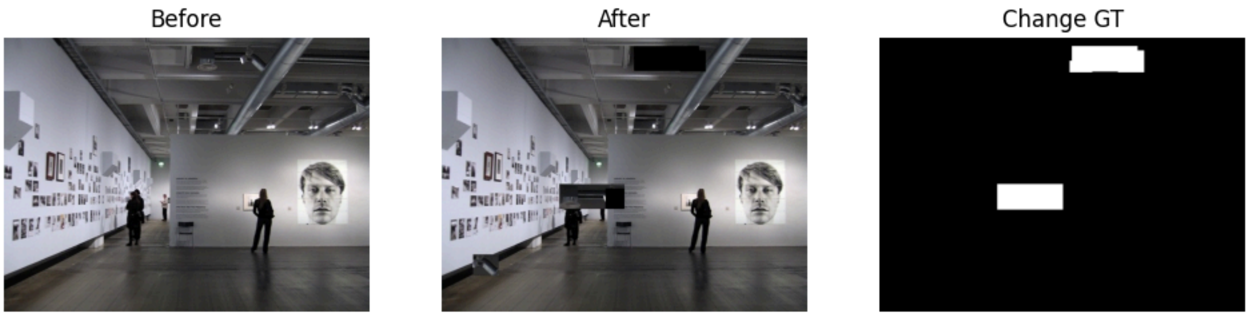
```
for _ in range(10):
    show_sample("/content/drive/MyDrive/gayoung/ba/pairs_out_cd","train")
```

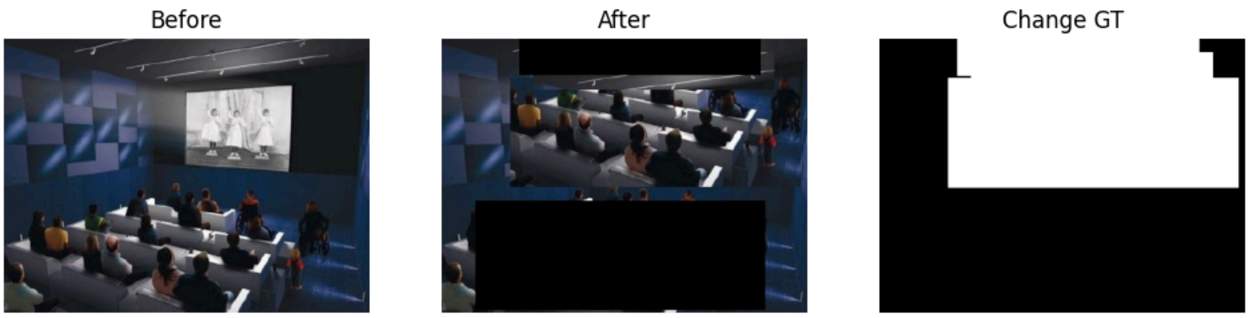

Before
After
Change GT

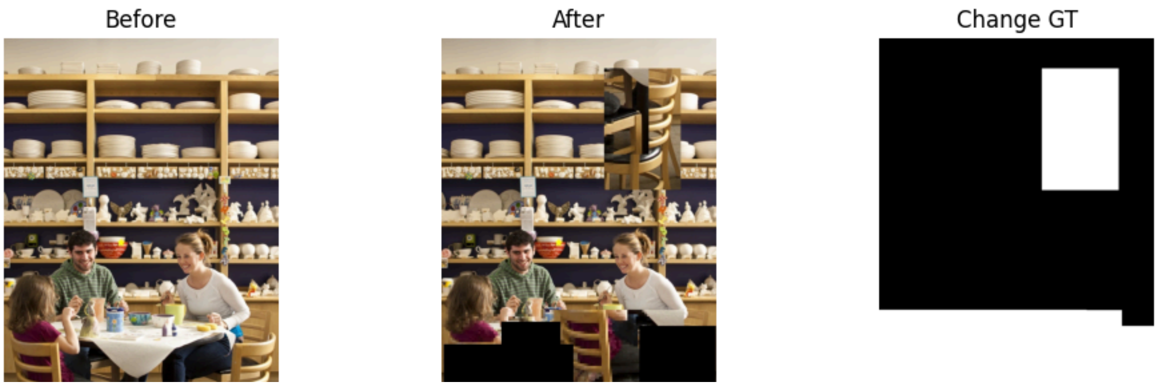

Before
After
Change GT

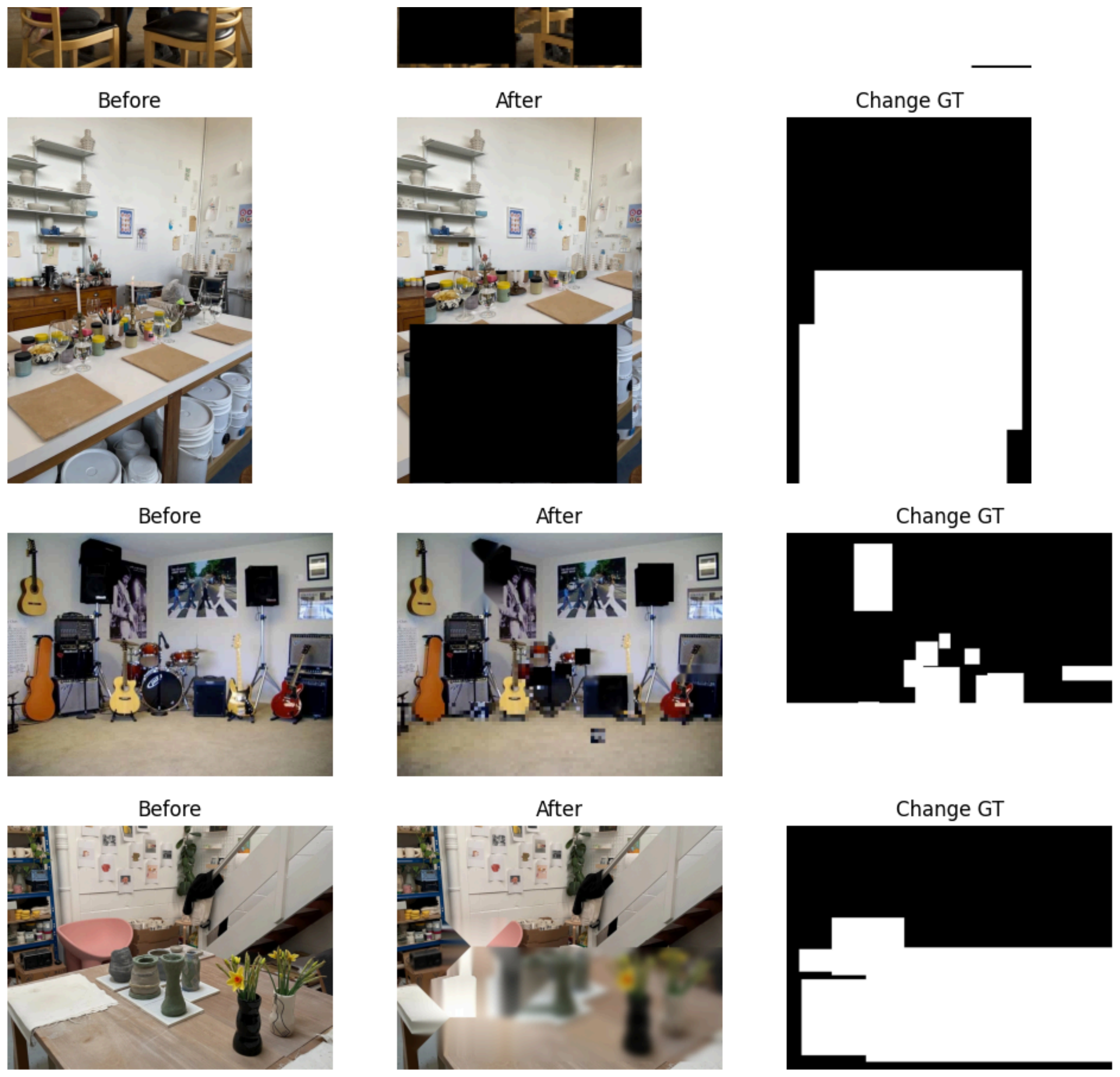

Before
After
Change GT


Before
After
Change GT


Before
After
Change GT


Before
After
Change GT


Before
After
Change GT


Before
After
Change GT
Before
After
Change GT
Before
After
Change GT

## (test) Before/After + GT 마스크 생성

```
# === TEST 쌍/마스크 생성 ===
import os, json, random, cv2, numpy as np
from pathlib import Path

random.seed(42)

BASE = Path("/content/drive/MyDrive/gayoung/ba/label_space_data")
IN_SPLIT = "dataset_test"   # <-- 테스트 split
OUT = Path("/content/drive/MyDrive/gayoung/ba/pairs_out_cd")

IMG_EXTS = {".jpg",".jpeg",".png",".bmp",".webp"}
YOLO_LBL_EXT = ".txt"

# 변경 합성 파라미터
APPLY_MASK_PROB = 0.85
MASK_MODE_SET = ["black","inpaint","rect","blur","pixel"]
RECT_JITTER = 0.12
PARTIAL_KEEP_PROB = 0.25
MIN_BOX_AREA = 20*20
MAX_MOVED_TRIES = 10

def is_hidden(p): return p.name.startswith(".") or p.name.startswith("._")
def ensure_dir(p): p.mkdir(parents=True, exist_ok=True)

def read_yolo(txt_path: Path):
    boxes = []
    if not txt_path.exists(): return boxes
    for line in open(txt_path,"r"):
        ps = line.strip().split()
        if len(ps) < 5: continue
        _, cx, cy, w, h = ps[:5]
        try: boxes.append(tuple(map(float,(cx,cy,w,h))))
        except: pass
    return boxes

def yolo_to_xywh(box, W,H):
    cx,cy,w,h = box
    bw, bh = int(w*W), int(h*H)
    x = int((cx - w/2)*W); y = int((cy - h/2)*H)
    x = max(0,x); y = max(0,y)
    x2 = min(W-1, x+bw); y2 = min(H-1, y+bh)
    return x,y, max(2,x2-x), max(2,y2-y)

def jitter_rect(x,y,w,h,W,H,rate):
    jx, jy = int(w*rate), int(h*rate)
    x = max(0, min(W-1, x + random.randint(-jx, jx)))
    y = max(0, min(H-1, y + random.randint(-jy, jy)))
    w = max(2, w + random.randint(-jx, jx))
    h = max(2, h + random.randint(-jy, jy))
    x2 = max(0, min(W-1, x+w)); y2 = max(0, min(H-1, y+h))
    return x, y, x2-x, y2-y

def inpaint_rect(img, x,y,w,h):
    m = np.zeros(img.shape[:2], np.uint8)
    cv2.rectangle(m,(x,y),(x+w,y+h),255,-1)
    return cv2.inpaint(img, m, 3, cv2.INPAINT_TELEA)

def blur_rect(img, x,y,w,h):
    roi = img[y:y+h, x:x+w]
    if roi.size==0: return img
    k = max(3, (min(w,h)//10)*2+1)
    img[y:y+h, x:x+w] = cv2.GaussianBlur(roi,(k,k),0)
    return img

def pixelate_rect(img, x,y,w,h, factor=0.15):
    roi = img[y:y+h, x:x+w]
    if roi.size==0: return img
    dw, dh = max(1,int(w*factor)), max(1,int(h*factor))
    small = cv2.resize(roi,(dw,dh))
    img[y:y+h, x:x+w] = cv2.resize(small,(w,h), interpolation=cv2.INTER_NEAREST)
    return img

def paste_move(img, x,y,w,h, W,H):
    src = img[y:y+h, x:x+w].copy()
    for _ in range(MAX_MOVED_TRIES):
        nx = random.randint(0, max(0,W-w)); ny = random.randint(0, max(0,H-h))
        img[ny:ny+h, nx:nx+w] = src
        img[y:y+h, x:x+w] = 0
        return img, [nx,ny,w,h]
    return img, None

def apply_change(after, change_mask, box_xywh, W,H):
    x,y,w,h = box_xywh
    if w*h < MIN_BOX_AREA: return after, change_mask
    x,y,w,h = jitter_rect(x,y,w,h,W,H, RECT_JITTER)
    mode = random.choice(MASK_MODE_SET + ["move","move"])
    if mode=="black":
        cv2.rectangle(after,(x,y),(x+w,y+h),(0,0,0),-1)
        cv2.rectangle(change_mask,(x,y),(x+w,y+h),255,-1)
    elif mode=="rect":
        patch = np.random.randint(0, 30, (h,w,3), dtype=np.uint8)
        after[y:y+h, x:x+w] = patch
        cv2.rectangle(change_mask,(x,y),(x+w,y+h),255,-1)
    elif mode=="inpaint":
        after[:] = inpaint_rect(after,x,y,w,h)
        cv2.rectangle(change_mask,(x,y),(x+w,y+h),255,-1)
    elif mode=="blur":
        after[:] = blur_rect(after,x,y,w,h)
        cv2.rectangle(change_mask,(x,y),(x+w,y+h),255,-1)
    elif mode=="pixel":
        after[:] = pixelate_rect(after,x,y,w,h,0.15)
        cv2.rectangle(change_mask,(x,y),(x+w,y+h),255,-1)
    elif mode=="move":
        after[:], moved = paste_move(after,x,y,w,h,W,H)
        cv2.rectangle(change_mask,(x,y),(x+w,y+h),255,-1)
        if moved is not None:
            nx,ny,nw,nh = moved
            cv2.rectangle(change_mask,(nx,ny),(nx+nw,ny+nh),255,-1)

    # 일부 컨투어 제거(부분 가림)
    if random.random() < PARTIAL_KEEP_PROB:
        cnts,_ = cv2.findContours(change_mask, cv2.RETR_EXTERNAL, cv2.CHAIN_APPROX_SIMPLE)
        for c in cnts:
            if cv2.contourArea(c) > MIN_BOX_AREA and random.random()<0.5:
                cv2.drawContours(change_mask,[c],-1,0,-1)
    return after, change_mask

def build_test():
    in_root = BASE/IN_SPLIT
    img_root = in_root/"images"
    lbl_root = in_root/"labels"

    out_b = OUT/"test"/"before_images"
    out_a = OUT/"test"/"after_images"
    out_y = OUT/"test"/"labels"
    for d in [out_b,out_a,out_y]: ensure_dir(d)

    meta = []
    classes = [d.name for d in img_root.iterdir() if d.is_dir() and not is_hidden(d)]
    total = 0

    for cls in classes:
        cls_img = img_root/cls
        cls_lbl = lbl_root/cls
        files = [p for p in cls_img.iterdir() if p.is_file() and p.suffix.lower() in IMG_EXTS and not is_hidden(p)]
        for imgp in files:
            base = imgp.stem
            lblp = cls_lbl/(base + YOLO_LBL_EXT)
            if not lblp.exists():
                # 라벨 없으면 스킵(원하면 변화 없음 샘플로 추가 가능)
                continue

            img = cv2.imread(str(imgp), cv2.IMREAD_COLOR)
            if img is None: continue
            H,W = img.shape[:2]
            boxes = read_yolo(lblp)

            after = img.copy()
            change_mask = np.zeros((H,W), np.uint8)
            if boxes and random.random() < APPLY_MASK_PROB:
                # 박스 중 일부만 변경
                bxywh = [yolo_to_xywh(b, W,H) for b in boxes]
                k = random.randint(1, max(1,len(bxywh)))
                for (x,y,w,h) in random.sample(bxywh, k=k):
                    after, change_mask = apply_change(after, change_mask, (x,y,w,h), W,H)

            # 저장(클래스 접두사)
            out_name = f"{cls}__{imgp.name}"
            cv2.imwrite(str(out_b/out_name), img)
            cv2.imwrite(str(out_a/out_name), after)
            cv2.imwrite(str(out_y/(Path(out_name).stem + ".png")), change_mask)

            meta.append({
                "split":"test",
                "class":cls,
                "before": str((out_b/out_name).as_posix()),
                "after":  str((out_a/out_name).as_posix()),
                "label":  str((out_y/(Path(out_name).stem + ".png")).as_posix()),
            })
            total += 1

    ensure_dir(OUT/"meta")
    with open(OUT/"meta"/"pairs_test.json","w") as f:
        json.dump(meta, f, indent=2, ensure_ascii=False)

    print(f"[dataset_test] 생성 쌍: {total}")
    print(f"출력: {OUT/'test'}")

build_test()
```

```
[dataset_test] 생성 쌍: 33
출력: /content/drive/MyDrive/gayoung/ba/pairs_out_cd/test
```

test 구축 결과

```
import os
root = "/content/drive/MyDrive/gayoung/ba/pairs_out_cd/test"
def count(p): return sum(len(fs) for _,_,fs in os.walk(p))
print("test before:", count(f"{root}/before_images"))
print("test after :", count(f"{root}/after_images"))
print("test labels:", count(f"{root}/labels"))
```

```
test before: 33
test after : 33
test labels: 33
```

## 학습

### 데이터셋 로더

1. 목적: (before, after, mask) 쌍을 로드하고 크기/정규화를 일관 적용
2. 입력: OUT/{train|val}/{before_images, after_images, labels}
3. 전처리:

- 이미지: [0,1] 정규화, HWC→CHW
- 마스크: **최근접 보간**으로 리사이즈, 0/255→{0,1}

4. 반환: (before[3×H×W], after[3×H×W], mask[1×H×W])

```
import glob, cv2, numpy as np, torch, torch.nn as nn, torch.nn.functional as F
from torch.utils.data import Dataset, DataLoader
from pathlib import Path

ROOT_OUT = "/content/drive/MyDrive/gayoung/ba/pairs_out_cd"
IMG_SIZE = (384,384)
BATCH    = 4
EPOCHS   = 40
LR       = 1e-3
DEVICE   = "cuda" if torch.cuda.is_available() else "cpu"

class PairDataset2In(Dataset):
    def __init__(self, root, split="train", size=(384,384)):
        self.root = Path(root)/split
        self.size = size
        bs = sorted(glob.glob(str(self.root/"before_images/*")))
        A  = {Path(p).name:p for p in glob.glob(str(self.root/"after_images/*"))}
        self.items=[]
        for b in bs:
            nm = Path(b).name
            y  = self.root/"labels"/(Path(nm).stem+".png")
            if nm in A and y.exists():
                self.items.append((b, A[nm], str(y)))
    def __len__(self): return len(self.items)
    def __getitem__(self, i):
        pb, pa, py = self.items[i]
        b = cv2.imread(pb)[:,:,::-1]; a = cv2.imread(pa)[:,:,::-1]
        y = cv2.imread(py, cv2.IMREAD_GRAYSCALE)
        if self.size:
            b = cv2.resize(b, self.size, interpolation=cv2.INTER_AREA)
            a = cv2.resize(a, self.size, interpolation=cv2.INTER_AREA)
            y = cv2.resize(y, self.size, interpolation=cv2.INTER_NEAREST)
        b = (b.astype(np.float32)/255.).transpose(2,0,1)
        a = (a.astype(np.float32)/255.).transpose(2,0,1)
        y = (y>0).astype(np.float32)[None,...]
        return torch.from_numpy(b), torch.from_numpy(a), torch.from_numpy(y)

```

## 모델: TinyChangeUNet

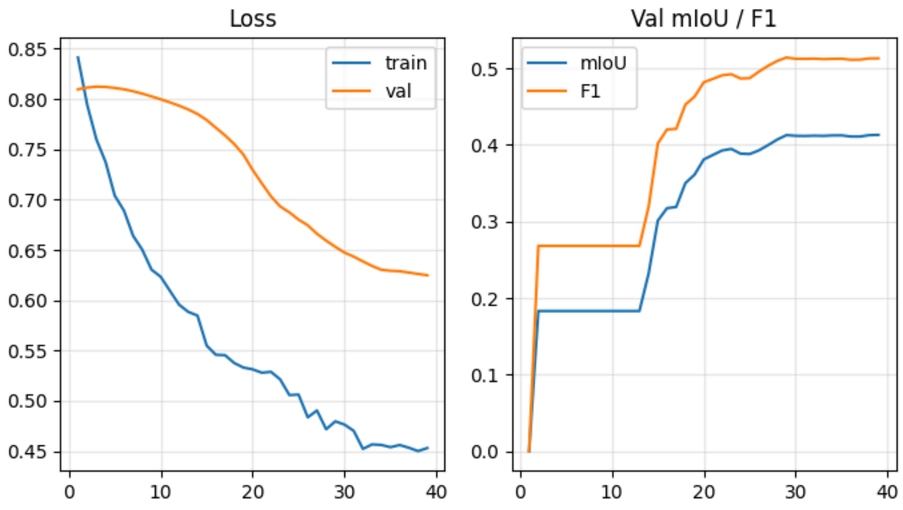
1. **아이디어**: before, after, 그리고 절대차(diff, 1채널)를 합쳐 **7채널** 입력 → 1×1 conv로 3채널 축소 → MobileNetV3(Small) 백본(사전학습) 인코더 → 경량 디코더(TransposeConv + DWConvBlock) → 1채널 로짓 출력
2. **스킵/채널**: 인코더 피처를 24/40/64/96으로 맞춰 디코더와 결합
3. **출력**: 원 해상도로 bilinear 업샘플링된 로짓(시그모이드 전)
4. **장점**: 파라미터 수가 작고 모바일 친화적이며 CD(변화감지) 특화의 `diff` 입력을 사용

```
import timm, torch
import torch.nn as nn
import torch.nn.functional as F

class DWConvBlock(nn.Module):
    def __init__(self, c_in, c_out):
        super().__init__()
        self.dw = nn.Conv2d(c_in, c_in, 3, 1, 1, groups=c_in, bias=False)
        self.bn1= nn.BatchNorm2d(c_in)
        self.pw = nn.Conv2d(c_in, c_out, 1, bias=False)
        self.bn2= nn.BatchNorm2d(c_out)
        self.act= nn.ReLU(inplace=True)
    def forward(self,x):
        x=self.dw(x); x=self.bn1(x); x=self.act(x)
        x=self.pw(x); x=self.bn2(x); x=self.act(x);
        return x

class TinyDecoder(nn.Module):
    def __init__(self, chs):  # [c1,c2,c3,c4]
        super().__init__()
        c1,c2,c3,c4 = chs
        self.up3 = nn.ConvTranspose2d(c4, c3, 2, 2); self.c3=DWConvBlock(c3+c3, c3)
        self.up2 = nn.ConvTranspose2d(c3, c2, 2, 2); self.c2=DWConvBlock(c2+c2, c2)
        self.up1 = nn.ConvTranspose2d(c2, c1, 2, 2); self.c1=DWConvBlock(c1+c1, c1)
    def forward(self, feats):
        f1,f2,f3,f4 = feats
        x = self.up3(f4); x=torch.cat([x,f3],1); x=self.c3(x)
        x = self.up2(x);  x=torch.cat([x,f2],1); x=self.c2(x)
        x = self.up1(x);  x=torch.cat([x,f1],1); x=self.c1(x)
        return x

class MobileNetV3Encoder(nn.Module):
    def __init__(self, out_indices=(0,1,2,3)):
        super().__init__()
        self.backbone = timm.create_model("mobilenetv3_small_100",
                                          pretrained=True, features_only=True,
                                          out_indices=out_indices)
        self.out_channels = self.backbone.feature_info.channels()
    def forward(self,x): return self.backbone(x)

class TinyChangeUNet(nn.Module):
    def __init__(self):
        super().__init__()
        # before(3) + after(3) + diff(1) = 7채널 → 3채널로 투영
        self.reduce = nn.Conv2d(7, 3, 1)
        self.encoder = MobileNetV3Encoder(out_indices=(0,1,2,3))
        c1,c2,c3,c4 = self.encoder.out_channels
        self.skip1 = nn.Conv2d(c1, 24, 1)
        self.skip2 = nn.Conv2d(c2, 40, 1)
        self.skip3 = nn.Conv2d(c3, 64, 1)
        self.bott  = nn.Conv2d(c4, 96, 1)
        self.decoder = TinyDecoder([24,40,64,96])
        self.head = nn.Conv2d(24, 1, 1)

    def forward(self, before, after):
        H, W = before.shape[-2], before.shape[-1]
        diff = torch.mean(torch.abs(before - after), dim=1, keepdim=True)  # N,1,H,W
        x = torch.cat([before, after, diff], dim=1)  # N,7,H,W
        x = self.reduce(x)
        f1,f2,f3,f4 = self.encoder(x)
        f1,f2,f3,f4 = self.skip1(f1), self.skip2(f2), self.skip3(f3), self.bott(f4)
        x = self.decoder([f1,f2,f3,f4])
        logit = self.head(x)
        return F.interpolate(logit, size=(H,W), mode='bilinear', align_corners=False)

```

## 학습/평가 루프

1. **핵심 기능**

- **손실**: BCE(with `pos_weight`) + Tversky 혼합(AMP/F16 안전).
- **클래스 불균형 완화**: train 소배치에서 **positive pixel ratio**를 추정해 `pos_weight` 자동 설정.
- **스케줄러**: 2 epoch 워밍업 + Cosine Decay.
- **EMA**: 부동 텐서만 추적, **EMA 가중치**로 검증/저장(안정성↑).
- **임계값 스윕**: 매 epoch마다 `sweep_streaming` 으로 **최적 th**와 (mIoU,F1) 로그.
- **조기 종료**: 검증 F1 **개선폭 < 0.005**가 12epoch 지속 시 stop.
- **로깅**: Loss/mIoU/F1 curve 저장(`live_curve.png`).



```
# ==== imports ====
import os, gc, math, numpy as np, torch, torch.nn as nn
from torch.utils.data import DataLoader
from tqdm.auto import tqdm
import matplotlib.pyplot as plt
from IPython.display import clear_output

# ==== 하이퍼파라미터 ====
ROOT_OUT = "/content/drive/MyDrive/gayoung/ba/pairs_out_cd"
IMG_SIZE  = 256
BATCH     = 8
EPOCHS    = 40
LR        = 3e-4                 # 손실 안정 위해 한 단계 낮춤 (원하면 1e-3로)
DEVICE    = "cuda" if torch.cuda.is_available() else "cpu"
SAVE_PATH = "/content/drive/MyDrive/gayoung/ba/change_tiny_mnv3_best.pth"

USE_POSTPROC = False             # 작은 블랍 제거(평가 시). 필요하면 True

torch.backends.cudnn.benchmark = True

# ------------------------------------------------------------
# 1) 손실 (FP16 안정화) + 디버그 지원
# ------------------------------------------------------------
class BCE_Tversky_FP16_dbg(nn.Module):
    def __init__(self, alpha=0.7, beta=0.3, eps=1e-3, pos_weight=None,
                 w_bce=0.6, w_tv=0.4):
        super().__init__()
        self.alpha, self.beta, self.eps = alpha, beta, eps
        self.w_bce, self.w_tv = w_bce, w_tv
        self.register_buffer("pos_weight_buf", None)
        if pos_weight is not None:
            self.pos_weight_buf = torch.as_tensor(pos_weight).reshape(1)
        self.bce = nn.BCEWithLogitsLoss(pos_weight=self.pos_weight_buf)

    def forward(self, pred, target, return_parts=False):
        pred = pred.clamp(-15, 15)
        b = self.bce(pred, target)                # BCE
        p = torch.sigmoid(pred)
        tp = (p*target).sum((2,3)).float()
        fp = (p*(1-target)).sum((2,3)).float()
        fn = ((1-p)*target).sum((2,3)).float()
        tv = (tp / (tp + self.alpha*fp + self.beta*fn + self.eps)).mean()
        tv_loss = (1.0 - tv).to(b.dtype)          # Tversky loss
        loss = self.w_bce*b + self.w_tv*tv_loss
        if return_parts:
            return loss, b.detach(), tv_loss.detach()
        return loss

# ------------------------------------------------------------
# 2) 지표 + (옵션) 작은 블랍 제거
# ------------------------------------------------------------
import torch.nn.functional as F
def clean_bin(pm_bin, k=3):
    # pm_bin: [N,1,H,W] 0/1 tensor
    return (F.avg_pool2d(pm_bin, k, 1, k//2) > 0.5).float()

@torch.no_grad()
def compute_metrics_from_sigmoid(pred_sigmoid, gt_bin, th=0.5, postproc=False):
    pm = (pred_sigmoid > th).float()
    if postproc:
        pm = clean_bin(pm, k=3)
    inter = (pm*gt_bin).sum((2,3))
    union = pm.sum((2,3)) + gt_bin.sum((2,3)) - inter + 1e-6
    iou = (inter/union).mean().item()
    f1  = (2*inter/(pm.sum((2,3))+gt_bin.sum((2,3))+1e-6)).mean().item()
    return iou, f1

# ------------------------------------------------------------
# 3) 로그릿 저장 없는 임계값 스윕 (EMA 상태에서 호출)
# ------------------------------------------------------------
def sweep_streaming(model, dl, device, th_grid, postproc=False):
    model.eval()
    t = torch.as_tensor(th_grid, device=device)   # [K]
    K = t.numel()
    inter = torch.zeros(K, device=device)
    union = torch.zeros(K, device=device)
    tp = torch.zeros(K, device=device)
    fp = torch.zeros(K, device=device)
    fn = torch.zeros(K, device=device)

    with torch.no_grad(), torch.amp.autocast('cuda', dtype=torch.float16):
        for b,a,y in dl:
            b,a,y = b.to(device), a.to(device), (y>0.5).to(device).float()
            logit = model(b,a).clamp(-15,15)
            p = torch.sigmoid(logit).float()
            if postproc:
                p = clean_bin((p>0.5).float(), k=3) * 1.0  # 근사 보정,
                p = p.clamp(0,1)                            # th를 다시 적용하므로 0/1 유지
                # 스윕 시엔 확률 기반이 더 낫지만, 후처리 쓰려면 간이근사로 사용

            p2 = p.flatten(2).transpose(1,2)       # [N,HW,1]
            y2 = y.flatten(2).transpose(1,2)
            pm = (p2 > t.view(1,1,-1)).float()     # [N,HW,K]

            pi = (pm*y2).sum(dim=(0,1))
            inter += pi
            u = pm.sum(dim=(0,1)) + y2.sum(dim=(0,1)) - pi
            union += torch.clamp(u, min=1e-6)

            tp += pi
            fp += (pm*(1-y2)).sum(dim=(0,1))
            fn += ((1-pm)*y2).sum(dim=(0,1))

    miou = (inter/union).cpu().numpy()
    f1   = (2*tp/torch.clamp(2*tp+fp+fn, min=1e-6)).cpu().numpy()
    j = int(np.argmax(f1))
    return {"th": float(t[j].item()), "mIoU": float(miou[j]), "F1": float(f1[j])}

# ------------------------------------------------------------
# 4) pos_weight 추정
# ------------------------------------------------------------
@torch.no_grad()
def estimate_pos_weight(dl, device, max_batches=20, clamp_to=10.0):
    pos, tot = 0, 0
    for i, (_, _, y) in enumerate(dl):
        y = (y>0.5).to(device).float()
        pos += y.sum().item()
        tot += y.numel()
        if i+1 >= max_batches: break
    neg = max(tot - pos, 1.0)
    raw = neg / max(pos, 1.0)
    pw  = float(np.sqrt(raw))
    if clamp_to is not None:
        pw = min(pw, clamp_to)
    return pw

# ------------------------------------------------------------
# 5) DataLoader
# ------------------------------------------------------------
tr = PairDataset2In(ROOT_OUT, "train", (IMG_SIZE, IMG_SIZE))
vl = PairDataset2In(ROOT_OUT, "val",   (IMG_SIZE, IMG_SIZE))

dl_tr = DataLoader(tr, batch_size=BATCH, shuffle=True,  num_workers=0, pin_memory=False, persistent_workers=False)
dl_vl = DataLoader(vl, batch_size=BATCH, shuffle=False, num_workers=0, pin_memory=False, persistent_workers=False)

# ------------------------------------------------------------
# 6) 모델/옵티마이저/코사인+워밍업/손실
# ------------------------------------------------------------
model = TinyChangeUNet().to(DEVICE)
opt   = torch.optim.AdamW(model.parameters(), lr=LR, weight_decay=1e-4, eps=1e-4)

pos_w = estimate_pos_weight(dl_tr, DEVICE, max_batches=20, clamp_to=10.0)
crit  = BCE_Tversky_FP16_dbg(alpha=0.7, beta=0.3, eps=1e-3,
                             w_bce=0.6, w_tv=0.4,
                             pos_weight=torch.tensor([pos_w], device=DEVICE))
print(f"[info] estimated pos_weight ≈ {pos_w:.2f}")

# 코사인 + 워밍업(에폭 기준)
WARMUP_EPOCHS = 2
ETA_MIN = 1e-5
BASE_LR = LR
def set_lr(lr):
    for g in opt.param_groups: g["lr"] = lr
def lr_at_epoch(ep):
    if ep < WARMUP_EPOCHS:
        return BASE_LR * (ep + 1) / max(1, WARMUP_EPOCHS)
    t = ep - WARMUP_EPOCHS
    T = max(1, EPOCHS - WARMUP_EPOCHS)
    return ETA_MIN + 0.5*(BASE_LR - ETA_MIN)*(1 + math.cos(math.pi * t / T))

# ------------------------------------------------------------
# 7) EMA (float 텐서만 추적)
# ------------------------------------------------------------
EMA_DECAY = 0.99
def build_ema(model):
    ema = {}
    for k, v in model.state_dict().items():
        if torch.is_floating_point(v):
            ema[k] = v.detach().clone()
    return ema

@torch.no_grad()
def ema_update(model, ema, decay=EMA_DECAY):
    msd = model.state_dict()
    for k in ema.keys():
        ema[k].mul_((decay)).add_(msd[k], alpha=1-decay)

@torch.no_grad()
def apply_ema_for_eval(model, ema):
    stash = {}
    msd = model.state_dict()
    for k, v in ema.items():
        stash[k] = msd[k].detach().clone()
        msd[k].copy_(v)
    return stash

@torch.no_grad()
def restore_from_stash(model, stash):
    msd = model.state_dict()
    for k, v in stash.items():
        msd[k].copy_(v)

ema = build_ema(model)

# ------------------------------------------------------------
# 8) 학습 루프
# ------------------------------------------------------------
scaler   = torch.amp.GradScaler('cuda')
history  = {"tr":[], "vl":[], "miou":[], "f1":[]}
best_f1  = -1.0
```

```python
bad      = 0
min_delta = 0.005
patience  = 12
best_th   = 0.5
did_print_val_ratio = False

for ep in range(EPOCHS):
    set_lr(lr_at_epoch(ep))

    # ---- Train ----
    model.train(); run=0; n=0
    pbar = tqdm(dl_tr, desc=f"Epoch {ep+1}/{EPOCHS} [train]")
    for b,a,y in pbar:
        b,a,y = b.to(DEVICE), a.to(DEVICE), y.to(DEVICE)
        opt.zero_grad(set_to_none=True)
        with torch.amp.autocast('cuda', dtype=torch.float16):
            logit = model(b,a)
            loss  = crit(logit, y)
        scaler.scale(loss).backward()
        scaler.unscale_(opt)
        nn.utils.clip_grad_norm_(model.parameters(), 1.0)
        scaler.step(opt); scaler.update()
        ema_update(model, ema)                # step 후 EMA 갱신
        run += loss.item()*b.size(0); n += b.size(0)
        pbar.set_postfix(loss=f"{loss.item():.4f}", lr=opt.param_groups[0]["lr"])
        del b,a,y,logit,loss
    tr_loss = run/max(1,n)

    # ---- Valid (EMA로 평가 & 저장도 EMA로) ----
    model.eval(); run=0; n=0; ious=[]; f1s=[]
    stash = apply_ema_for_eval(model, ema)  # EMA 적용
    pbar = tqdm(dl_vl, desc=f"Epoch {ep+1}/{EPOCHS} [valid]")
    with torch.no_grad():
        pos_pix, tot_pix = 0, 0
        for b,a,y in pbar:
            b,a,y = b.to(DEVICE), a.to(DEVICE), y.to(DEVICE)
            with torch.amp.autocast('cuda', dtype=torch.float16):
                logit = model(b,a).clamp(-15,15)
                # 파트 로깅 원하면 아래처럼:
                # l, b_part, tv_part = crit(logit, y, return_parts=True)
                # loss = l.item()
                loss = crit(logit, y).item()
                s = torch.sigmoid(logit).float()
                mi, mf = compute_metrics_from_sigmoid(
                    s, (y>0.5).float(), th=best_th, postproc=USE_POSTPROC
                )
            run += loss*b.size(0); n += b.size(0)
            ious.append(mi); f1s.append(mf)
            pbar.set_postfix(loss=f"{loss:.4f}")
            if not did_print_val_ratio:
                pos_pix += (y>0.5).float().sum().item()
                tot_pix += y.numel()
            del b,a,y,logit,s
    if not did_print_val_ratio:
        did_print_val_ratio = True
        print(f"[val] positive pixel ratio ≈ {pos_pix/max(1,tot_pix):.6f}")

    vl_loss = run/max(1,n); miou=float(np.mean(ious)); mf1=float(np.mean(f1s))

    # ---- Save best & Early stop ----
    improved = (mf1 > best_f1 + min_delta)
    if improved:
        best_f1 = mf1; bad = 0
        torch.save(model.state_dict(), SAVE_PATH)   # 현재는 EMA 가중치가 들어가있음
        print("  ↳ best(F1) 갱신, 저장(EMA):", SAVE_PATH)
    else:
        bad += 1
        if bad >= patience:
            print("  ↳ early stop (F1)")
            restore_from_stash(model, stash)
            break

    # ---- 임계값 스윕 (EMA 상태에서 수행) ----
    grid = np.linspace(0.02, 0.40, 40)  # ← 요청한 구간으로 확장
    sweep = sweep_streaming(model, dl_vl, DEVICE, grid, postproc=USE_POSTPROC)
    best_th = sweep["th"]
    print(f"  ↳ [TH SWEEP/EMA] th={best_th:.2f} | mIoU={sweep['mIoU']:.3f} | F1={sweep['F1']:.3f}")

    # EMA 적용 전 가중치 복구
    restore_from_stash(model, stash)

    history["tr"].append(tr_loss); history["vl"].append(vl_loss)
    history["miou"].append(miou);  history["f1"].append(mf1)
    print(f"[{ep:02d}] train {tr_loss:.4f} | val {vl_loss:.4f} | mIoU {miou:.3f} | F1 {mf1:.3f} | th {best_th:.2f}")

    # ---- 메모리 정리 + 라이브 곡선 저장 ----
    torch.cuda.empty_cache(); gc.collect()
    clear_output(wait=True)
    plt.figure(figsize=(7,4))
    xs = np.arange(1, len(history["tr"]) + 1)
    plt.subplot(1,2,1); plt.title("Loss"); plt.plot(xs, history["tr"], label="train"); plt.plot(xs, history["vl"], labe
    plt.subplot(1,2,2); plt.title("Val mIoU / F1"); plt.plot(xs, history["miou"], label="mIoU"); plt.plot(xs, history["
    plt.tight_layout(); plt.savefig("live_curve.png"); plt.close()

print("="*50)
print(f"학습 종료 | 총 Epoch: {len(history['tr'])}")
print(f"최고 F1(EMA): {best_f1:.3f} @ th={best_th:.2f}")
print(f"마지막 Epoch({len(history['tr'])-1})")
print(f"  train loss={history['tr'][-1]:.4f}")
print(f"  val loss  ={history['vl'][-1]:.4f}")
print(f"  mIoU={history['miou'][-1]:.3f}, F1={history['f1'][-1]:.3f}")
print("="*50)
```

```
Epoch  40/40  [train]:  100%                                15/15  [00:10<00:00,    1.43it/s,  loss=0.5081,  lr=1.05e-5]

Epoch  40/40  [valid]:  100%                                4/4  [00:03<00:00,    1.03it/s,  loss=0.5770]
  ↳ early stop (F1)
==================================================
학습 종료 | 총 Epoch: 39
최고 F1(EMA): 0.510 @ th=0.36
마지막 Epoch(38)
  train loss=0.4530
  val loss  =0.6248
  mIoU=0.413, F1=0.513
==================================================
```

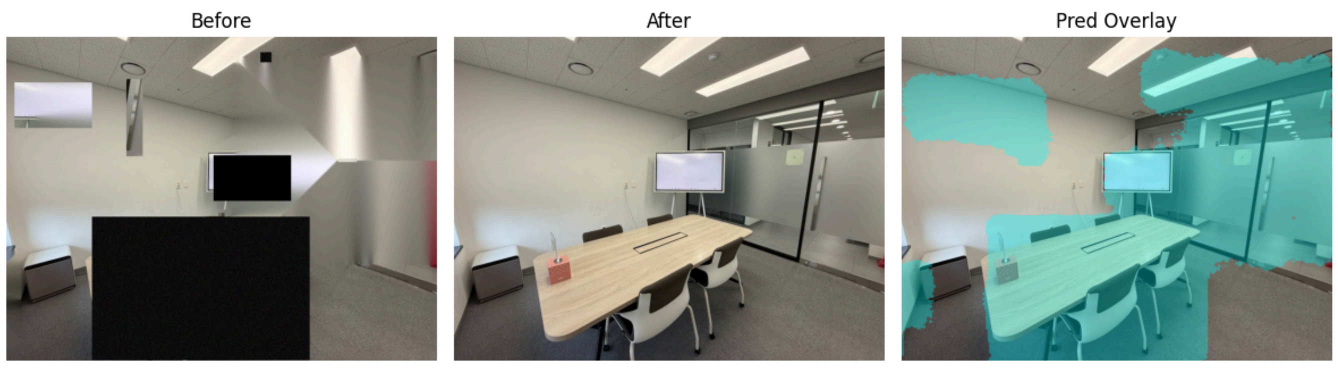
## TEST Eval

```
# ==== Self-contained TEST Eval (safe after Colab restart) ====
import os, glob, cv2, numpy as np, torch
import torch.nn.functional as F
from torch.utils.data import DataLoader
from tqdm.auto import tqdm

# --- 필수 클래스 준비 확인 ---
assert 'TinyChangeUNet' in globals(), "TinyChangeUNet 클래스를 먼저 정의/임포트하세요."
assert 'PairDataset2In' in globals(), "PairDataset2In 클래스를 먼저 정의/임포트하세요."

# --- 공통 설정 (먼저 정의!) ---
DEVICE = 'cuda' if torch.cuda.is_available() else 'cpu'
AMP_DEVICE = 'cuda' if DEVICE == 'cuda' else 'cpu'
AMP_DTYPE  = torch.float16 if DEVICE == 'cuda' else torch.bfloat16
ROOT_OUT   = "/content/drive/MyDrive/gayoung/ba/pairs_out_cd"
IMG_SIZE   = 256
BATCH      = 8
USE_POSTPROC = False
SAVE_PATH  = "/content/drive/MyDrive/gayoung/ba/change_tiny_mnv3_best.pth"

# --- 유틸 (이 셀에 같이 둠) ---
def clean_bin(pm_bin, k=3):
    return (F.avg_pool2d(pm_bin, k, 1, k//2) > 0.5).float()

@torch.no_grad()
def compute_metrics_from_sigmoid(pred_sigmoid, gt_bin, th=0.5, postproc=False):
    pm = (pred_sigmoid > th).float()
    if postproc:
        pm = clean_bin(pm, k=3)
    inter = (pm*gt_bin).sum((2,3))
    union = pm.sum((2,3)) + gt_bin.sum((2,3)) - inter + 1e-6
    iou = (inter/union).mean().item()
    f1  = (2*inter/(pm.sum((2,3))+gt_bin.sum((2,3))+1e-6)).mean().item()
    return iou, f1

@torch.no_grad()
def sweep_streaming(model, dl, device, th_grid=None, postproc=False):
    import numpy as _np
    if th_grid is None: th_grid = _np.linspace(0.35, 0.65, 13)
    t = torch.as_tensor(th_grid, device=device)   # [K]
    K = t.numel()
    inter = torch.zeros(K, device=device)
    union = torch.zeros(K, device=device)
    tp = torch.zeros(K, device=device)
    fp = torch.zeros(K, device=device)
    fn = torch.zeros(K, device=device)

    with torch.amp.autocast(device_type=AMP_DEVICE, dtype=AMP_DTYPE):
        for b,a,y in dl:
            b,a,y = b.to(device), a.to(device), (y>0.5).to(device).float()
            logit = model(b,a).clamp(-15,15)
            p = torch.sigmoid(logit).float()
            if postproc:
                p = clean_bin((p>0.5).float(), k=3) * 1.0
                p = p.clamp(0,1)

            p2 = p.flatten(2).transpose(1,2)       # [N,HW,1]
            y2 = y.flatten(2).transpose(1,2)
            pm = (p2 > t.view(1,1,-1)).float()     # [N,HW,K]
            pi = (pm*y2).sum(dim=(0,1))
            inter += pi
            u = pm.sum(dim=(0,1)) + y2.sum(dim=(0,1)) - pi
            union += torch.clamp(u, min=1e-6)
            tp += pi
            fp += (pm*(1-y2)).sum(dim=(0,1))
            fn += ((1-pm)*y2).sum(dim=(0,1))

    miou = (inter/union).cpu().numpy()
    f1   = (2*tp/torch.clamp(2*tp+fp+fn, min=1e-6)).cpu().numpy()
    j = int(np.argmax(f1))
    return {"th": float(t[j].item()), "mIoU": float(miou[j]), "F1": float(f1[j])}

# --- 모델 로드 (EMA가 저장된 체크포인트) ---
model = TinyChangeUNet().to(DEVICE).eval()
state = torch.load(SAVE_PATH, map_location=DEVICE)
model.load_state_dict(state, strict=True)

# --- 데이터로더 ---
vl = PairDataset2In(ROOT_OUT, "val",  (IMG_SIZE, IMG_SIZE))
dl_vl = DataLoader(vl, batch_size=BATCH, shuffle=False, num_workers=0)
ts = PairDataset2In(ROOT_OUT, "test", (IMG_SIZE, IMG_SIZE))
dl_ts = DataLoader(ts, batch_size=BATCH, shuffle=False, num_workers=0)

# --- 임계값 스윕 (val) ---
grid = np.linspace(0.02, 0.40, 40)
sweep = sweep_streaming(model, dl_vl, DEVICE, grid, postproc=USE_POSTPROC)
best_th = sweep["th"]
print(f"[VAL SWEEP] th={best_th:.3f} | mIoU={sweep['mIoU']:.3f} | F1={sweep['F1']:.3f}")

# --- 테스트 평가 + PNG 저장 (의존 함수 제거 버전: 연속 번호로 저장) ---
os.makedirs("test_preds", exist_ok=True)

@torch.no_grad()
def eval_and_dump(dl, th):
    ious, f1s = [], []
    global_idx = 0
    for b,a,y in tqdm(dl, desc="TEST"):
        b,a,y = b.to(DEVICE), a.to(DEVICE), (y>0.5).to(DEVICE).float()
        with torch.amp.autocast(device_type=AMP_DEVICE, dtype=AMP_DTYPE):
            logit = model(b,a).clamp(-15,15)
            s = torch.sigmoid(logit).float()

        mi, mf = compute_metrics_from_sigmoid(s, y, th=th, postproc=USE_POSTPROC)
        ious.append(mi); f1s.append(mf)

        pm = (s > th).float()
        if USE_POSTPROC: pm = clean_bin(pm, k=3)
        pm = (pm*255).byte().cpu().numpy()  # [N,1,H,W]

        N = pm.shape[0]
        for j in range(N):
            cv2.imwrite(f"test_preds/{global_idx:05d}.png", pm[j,0])
            global_idx += 1

        del b,a,y,logit,s,pm
    return float(np.mean(ious)), float(np.mean(f1s))

miou_ts, f1_ts = eval_and_dump(dl_ts, best_th)
print("="*60)
print(f"[TEST] mIoU={miou_ts:.3f} | F1={f1_ts:.3f} @ th={best_th:.2f} | postproc={USE_POSTPROC}")
print("pred png → ./test_preds/*.png")

```

```
WARNING:timm.models._builder:Unexpected keys (classifier.bias, classifier.weight, conv_head.bias, conv_head.weight) foun
[VAL SWEEP] th=0.361 | mIoU=0.481 | F1=0.650
TEST: 100%                                        5/5 [00:51<00:00, 10.03s/it]
============================================================
[TEST] mIoU=0.559 | F1=0.638 @ th=0.36 | postproc=False
pred png → ./test_preds/*.png
```

test 결과 예시 시각화

```
import cv2, matplotlib.pyplot as plt, numpy as np

# 파일 경로
pb = "/content/drive/MyDrive/gayoung/ba/pairs_out_cd/test/after_images/STUDY_ROOM__Image_4.jpg"
pa = "/content/drive/MyDrive/gayoung/ba/pairs_out_cd/test/before_images/STUDY_ROOM__Image_4.jpg"
pp = "/content/test_preds/00029.png"

# 로드
B  = cv2.imread(pb, cv2.IMREAD_COLOR)[:,:,::-1]
A  = cv2.imread(pa, cv2.IMREAD_COLOR)[:,:,::-1]
PR = cv2.imread(pp, cv2.IMREAD_GRAYSCALE)

# 사이즈 정렬(After 기준)
H,W = A.shape[:2]
if B.shape[:2] != (H,W): B = cv2.resize(B, (W,H), interpolation=cv2.INTER_LINEAR)
if PR.shape[:2]!= (H,W): PR= cv2.resize(PR,(W,H), interpolation=cv2.INTER_NEAREST)

# overlay 함수
def overlay(rgb, mask, color=(0,255,255), alpha=0.35):
    if mask.dtype != np.uint8: mask = mask.astype(np.uint8)
    m = (mask>127).astype("uint8")
    over = (rgb*(1-alpha) + np.array(color,dtype=np.uint8).reshape(1,1,3)*alpha).astype(np.uint8)
    out = rgb.copy(); out[m>0] = over[m>0]
    return out

ov_pred = overlay(A, PR, color=(0,255,255), alpha=0.35)

# 시각화
plt.figure(figsize=(12,5))
plt.subplot(1,3,1); plt.imshow(B);       plt.title("Before"); plt.axis("off")
plt.subplot(1,3,2); plt.imshow(A);       plt.title("After"); plt.axis("off")
plt.subplot(1,3,3); plt.imshow(ov_pred); plt.title("Pred Overlay"); plt.axis("off")
plt.tight_layout()
plt.show()
```



## CoreML 변환

```
import torch

model = TinyChangeUNet().eval().to('cpu')
state = torch.load(SAVE_PATH, map_location='cpu')
model.load_state_dict(state, strict=True)

dummy_b = torch.rand(1,3,256,256)
dummy_a = torch.rand(1,3,256,256)

class Wrapper(torch.nn.Module):
    def __init__(self, net):
```

```python
        super().__init__(); self.net = net
    def forward(self, before, after):
        logits = self.net(before, after)        # (1,1,H,W)
        return logits

ts = torch.jit.trace(Wrapper(model), (dummy_b, dummy_a))
torch.jit.save(ts, "change_ts.pt")

```

```
WARNING:timm.models._builder:Unexpected keys (classifier.bias, classifier.weight, conv_head.bias, conv_head.weight) foun
```

```python
!pip install -U "coremltools>=7.2,<8", "numpy<2"
```

숨겨진 출력 표시

CoreML 변환

```python
# ==== 0) imports ====
import torch, timm
import torch.nn as nn
import torch.nn.functional as F

# ==== 1) encoder  ====
class MobileNetV3Encoder(nn.Module):
    def __init__(self, out_indices=(0,1,2,3), pretrained=False, model_name="mobilenetv3_small_100"):
        super().__init__()
        self.backbone = timm.create_model(model_name, pretrained=pretrained,
                                          features_only=True, out_indices=out_indices)
        self.out_channels = self.backbone.feature_info.channels()
    def forward(self, x):
        return self.backbone(x)

# ==== 2) depthwise separable conv ====
class SepConvBN(nn.Module):
    def __init__(self, in_c, out_c):
        super().__init__()
        self.dw  = nn.Conv2d(in_c, in_c, 3, padding=1, groups=in_c, bias=False)
        self.bn1 = nn.BatchNorm2d(in_c)
        self.pw  = nn.Conv2d(in_c, out_c, 1, bias=False)
        self.bn2 = nn.BatchNorm2d(out_c)
    def forward(self, x):
        x = F.relu(self.bn1(self.dw(x)), inplace=True)
        x = F.relu(self.bn2(self.pw(x)), inplace=True)
        return x

# ==== 3) 디코더 ====
class DecoderCompat(nn.Module):
    def __init__(self):
        super().__init__()
        self.up3 = nn.ConvTranspose2d(96, 64, kernel_size=2, stride=2)  # matches [96,64,2,2]
        self.c3  = SepConvBN(128, 64)                                   # dw:128, pw:64
        self.up2 = nn.ConvTranspose2d(64, 40, kernel_size=2, stride=2)  # [64,40,2,2]
        self.c2  = SepConvBN(80, 40)                                    # dw:80,  pw:40
        self.up1 = nn.ConvTranspose2d(40, 24, kernel_size=2, stride=2)  # [40,24,2,2]
        self.c1  = SepConvBN(48, 24)                                    # dw:48,  pw:24
    def forward(self, s1, s2, s3, b):
        x = self.up3(b);  x = torch.cat([x, s3], dim=1); x = self.c3(x)
        x = self.up2(x);  x = torch.cat([x, s2], dim=1); x = self.c2(x)
        x = self.up1(x);  x = torch.cat([x, s1], dim=1); x = self.c1(x)
        return x

# ==== 4) 전체 네트워크  ====
class TinyChangeUNetV1Compat(nn.Module):
    def __init__(self):
        super().__init__()
        self.reduce  = nn.Conv2d(7, 3, 1)
        self.encoder = MobileNetV3Encoder(out_indices=(0,1,2,3), pretrained=False)
        c1, c2, c3, c4 = self.encoder.out_channels
        # skip을 24/40/64로 투영
        self.skip1 = nn.Conv2d(c1, 24, 1)
        self.skip2 = nn.Conv2d(c2, 40, 1)
        self.skip3 = nn.Conv2d(c3, 64, 1)
        # bottleneck을 96으로 투영 (up3 in_channels=96과 일치)
        self.bott  = nn.Conv2d(c4, 96, 1)
        self.decoder = DecoderCompat()
        self.head    = nn.Conv2d(24, 1, 1)
    def forward(self, before, after):
        diff = (after - before).abs().mean(dim=1, keepdim=True)
        x7   = torch.cat([before, after, diff], dim=1)
        x3   = self.reduce(x7)
        f1, f2, f3, f4 = self.encoder(x3)
        s1, s2, s3, b = self.skip1(f1), self.skip2(f2), self.skip3(f3), self.bott(f4)
        x = self.decoder(s1, s2, s3, b)
        return self.head(x)  # logits

# ==== 5) 내보내기용 래퍼 ====
class WrappedForExport(nn.Module):
    def __init__(self, net, mean=(0.485,0.456,0.406), std=(0.229,0.224,0.225)):
        super().__init__(); self.net = net.eval()
        self.register_buffer("mean", torch.tensor(mean).view(1,3,1,1))
        self.register_buffer("std",  torch.tensor(std ).view(1,3,1,1))
    def forward(self, before_u8, after_u8):
        b = (before_u8/255.0 - self.mean) / self.std
        a = (after_u8 /255.0 - self.mean) / self.std
        return self.net(b, a)

# ==== 6) 체크포인트 로드  ====
ckpt = "/content/drive/MyDrive/gayoung/ba/change_tiny_mnv3_best.pth"
net = TinyChangeUNetV1Compat().eval()
state = torch.load(ckpt, map_location="cpu")
net.load_state_dict(state, strict=True)

# ==== 7) TorchScript 저장 ====
H=W=256
wrapped = WrappedForExport(net).eval()
ts = torch.jit.trace(wrapped, (torch.rand(1,3,H,W)*255.0, torch.rand(1,3,H,W)*255.0))
ts.save("change_ts.pt")
print("✔ saved TorchScript -> change_ts.pt")

```

```
✔ saved TorchScript -> change_ts.pt
```

```
!pip install -U "coremltools>=7.2,<8" "numpy<2"

import coremltools as ct, torch
ts = torch.jit.load("change_ts.pt", map_location="cpu")
inp_b = ct.ImageType(name="before", shape=(1,3,256,256))
inp_a = ct.ImageType(name="after",  shape=(1,3,256,256))
mlmodel_fp16 = ct.convert(
    ts,
    inputs=[inp_b, inp_a],
    convert_to="mlprogram",
    compute_precision=ct.precision.FLOAT16,
    minimum_deployment_target=ct.target.iOS16,
)

mlmodel_fp16.save("change_unet_fp16.mlpackage")


```

```
/bin/bash: -c: line 1: syntax error near unexpected token `('
/bin/bash: -c: line 1: `pip install -U "coremltools>=7.2,<8" "numpy<2"  (설치 후 런타임 재시작)'
WARNING:coremltools:Support for converting Torch Script Models is experimental. If possible you should use a traced mode
Converting PyTorch Frontend ==> MIL Ops: 100%|██████████| 384/385 [00:00<00:00, 3967.26 ops/s]
Running MIL frontend_pytorch pipeline: 100%|██████████| 5/5 [00:00<00:00, 111.17 passes/s]
Running MIL default pipeline: 100%|██████████| 78/78 [00:01<00:00, 68.58 passes/s]
Running MIL backend_mlprogram pipeline: 100%|██████████| 12/12 [00:00<00:00, 157.97 passes/s]
```

로컬

```
# convert_to_mlpackage.py
import torch, torch.nn as nn, torch.nn.functional as F
import coremltools as ct
from pathlib import Path

# === 입력 TS 파일명 ===
TS_FILE = "change_ts.pt"

# 1) 원본 TorchScript 로드 (before, after 두 장을 인자로 받는 형태)
ts_core = torch.jit.load(TS_FILE, map_location="cpu").eval()

# 2) 전처리(/255 -> ImageNet mean/std) 래퍼 (항상 /255로, trace 안전)
IMN_MEAN = torch.tensor([0.485,0.456,0.406]).view(1,3,1,1)
IMN_STD  = torch.tensor([0.229,0.224,0.225]).view(1,3,1,1)

class PreprocWrapperTS(nn.Module):
    def __init__(self, ts_mod, out_size=None):
        super().__init__()
        self.ts = ts_mod
        self.out_size = out_size

```