Object Detection using RCNN

```
!pip install -q --upgrade selectivesearch torch_snippets
```

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  Building wheel for selectivesearch (setup.py) ... done
  Building wheel for typing (setup.py) ... done
```

```
from torch_snippets import *
import selectivesearch
from torchvision import transforms, models, datasets
from torch_snippets import Report
from torchvision.ops import nms
device = 'cuda' if torch.cuda.is_available() else 'cpu'
import numpy as np
```

```
IMAGE_ROOT = '../input/open-images-bus-trucks/images/images'
DF_RAW = pd.read_csv('../input/open-images-bus-trucks/df.csv')
print(DF_RAW.head())
```

```
              ImageID  Source LabelName  Confidence      XMin      XMax  \
0  0000599864fd15b3  xclick       Bus           1  0.343750  0.908750
1  00006bdb1eb5cd74  xclick     Truck           1  0.276667  0.697500
2  00006bdb1eb5cd74  xclick     Truck           1  0.702500  0.999167
3  00010bf498b64bab  xclick       Bus           1  0.156250  0.371250
4  00013f14dd4e168f  xclick       Bus           1  0.287500  0.999375

       YMin      YMax  IsOccluded  IsTruncated  ...  IsDepiction  IsInside  \
0  0.156162  0.650047           1            0  ...            0         0
1  0.141604  0.437343           1            0  ...            0         0
2  0.204261  0.409774           1            1  ...            0         0
3  0.269188  0.705228           0            0  ...            0         0
4  0.194184  0.999062           0            1  ...            0         0

   XClick1X  XClick2X  XClick3X  XClick4X  XClick1Y  XClick2Y  XClick3Y  \
0  0.421875  0.343750  0.795000  0.908750  0.156162  0.512700  0.650047
1  0.299167  0.276667  0.697500  0.659167  0.141604  0.241855  0.352130
2  0.849167  0.702500  0.906667  0.999167  0.204261  0.398496  0.409774
3  0.274375  0.371250  0.311875  0.156250  0.269188  0.493882  0.705228
4  0.920000  0.999375  0.648750  0.287500  0.194184  0.303940  0.999062

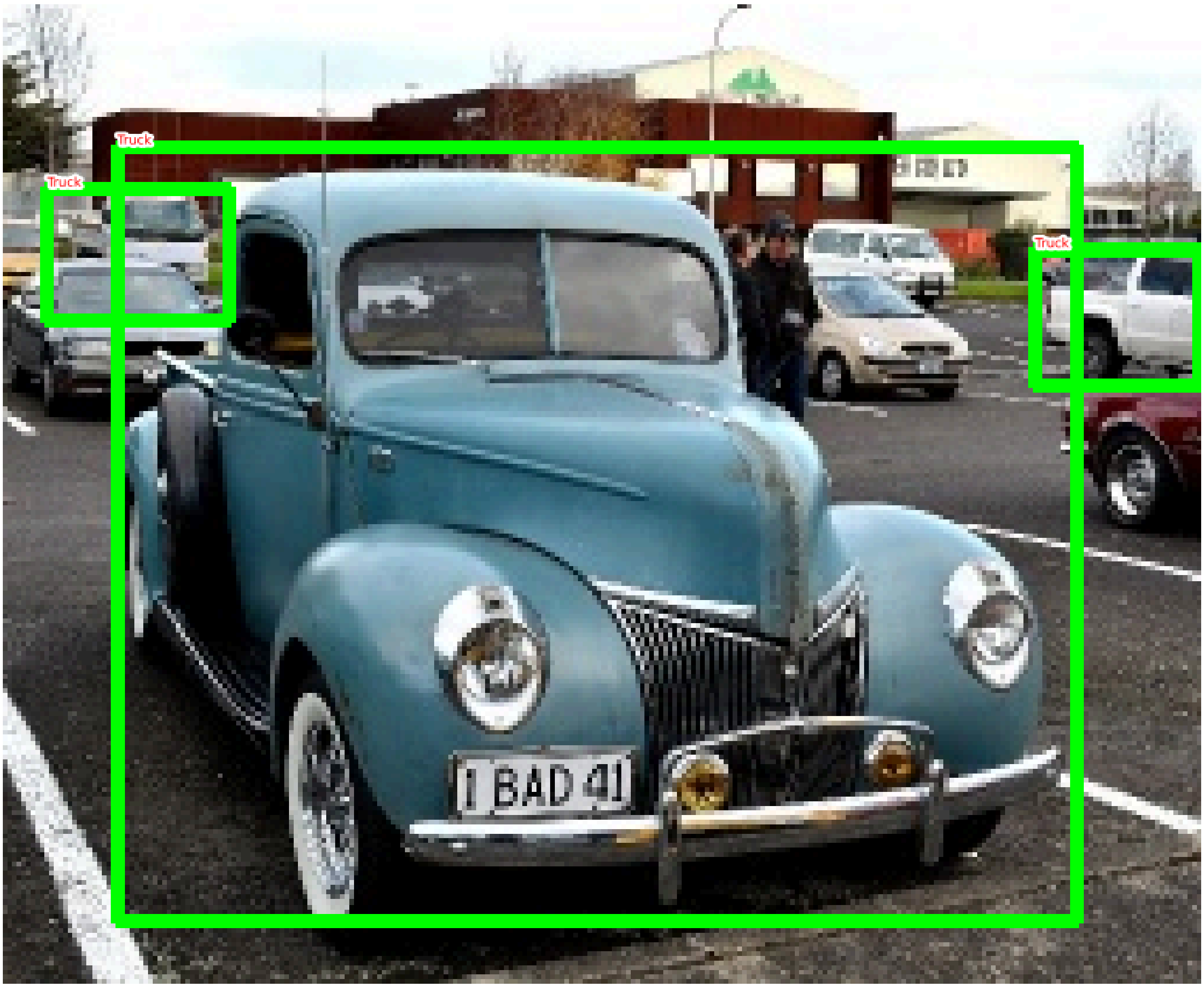
   XClick4Y
0  0.457197
1  0.437343
2  0.295739
3  0.521691
4  0.523452

[5 rows x 21 columns]
```

```
class OpenImages(Dataset):
    def __init__(self, df, image_folder=IMAGE_ROOT):
        self.root = image_folder
        self.df = df
        self.unique_images = df['ImageID'].unique()
    def __len__(self): return len(self.unique_images)
    def __getitem__(self, ix):
        image_id = self.unique_images[ix]
        image_path = f'{self.root}/{image_id}.jpg'
        image = cv2.imread(image_path, 1)[...,::-1] # convert BGR to RGB
        # Basically x[...], it is similar to cv2.imread(image_path, 1)[:, :, ::-1], but t
        h, w, _ = image.shape
        df = self.df.copy()
        df = df[df['ImageID'] == image_id]
        boxes = df['XMin,YMin,XMax,YMax'.split(',')].values
        boxes = (boxes * np.array([w,h,w,h])).astype(np.uint16).tolist() #boxes in accord
        classes = df['LabelName'].values.tolist()
        return image, boxes, classes, image_path
ds = OpenImages(df=DF_RAW)
```

For some images, there are multiple bounding boxes that may/may not belong to the same class. Below is an example:

```
im, bbs, clss, _ = ds[6]
show(im, bbs=bbs, texts=clss, sz=10)
print(bbs)
```




```
[[9, 39, 48, 67], [24, 30, 229, 195], [220, 52, 255, 81]]
```

```
im, bbs, clss, _ = ds[15]
show(im, bbs=bbs, texts=clss, sz=10)
print(bbs)
```


```
[[77, 90, 104, 118]]
```

The dimensions of the bounding box of the bus object is best understood in the following way -

![42193EA1-F670-417C-B5CD-37714DDBD836_1_201_a.jpeg]

SelectiveSearch to generate region proposals

SelectiveSearch is a region proposal algorithm used for object localization where it generates proposals of regions that are likely to be grouped together based on their pixel intensities. SelectiveSearch groups pixels based on the hierarchical grouping of similar pixels, which, in turn, leverages the color, texture, size, and shape compatibility of content within an image.

```
def extract_candidates(img):
    img_lbl, regions = selectivesearch.selective_search(img, scale=200, min_size=100)
    img_area = np.prod(img.shape[:2])
    candidates = []
    for r in regions:
        if r['rect'] in candidates: continue
        if r['size'] < (0.05*img_area): continue
        if r['size'] > (1*img_area): continue
        x, y, w, h = r['rect']
        candidates.append(list(r['rect']))
    return candidates

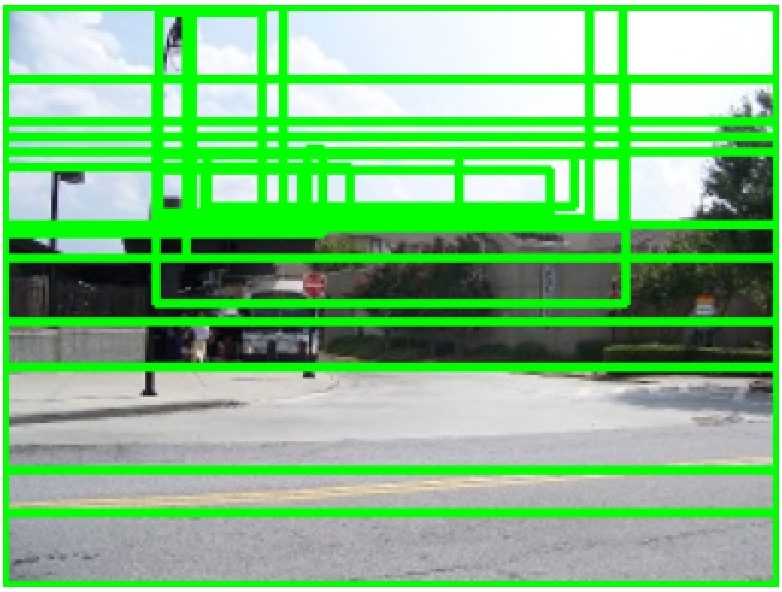
#how iou works
def extract_iou(boxA, boxB, epsilon=1e-5):
    x1 = max(boxA[0], boxB[0])
    y1 = max(boxA[1], boxB[1])
    x2 = min(boxA[2], boxB[2])
    y2 = min(boxA[3], boxB[3])
    width = (x2 - x1)  #change in x-direction
    height = (y2 - y1)  #change in y-direction
    if (width<0) or (height <0):
        return 0.0
    area_overlap = width * height # this was calculated by x1, y1, x2, y2
    area_a = (boxA[2] - boxA[0]) * (boxA[3] - boxA[1])
    area_b = (boxB[2] - boxB[0]) * (boxB[3] - boxB[1])
    area_combined = area_a + area_b - area_overlap
    iou = area_overlap / (area_combined+epsilon)
    return iou
```

Selectivesearch module

The selectivesearch creates multiple candidate bounding boxes randomly, to be passed along with the input image. The IoU (Intersection over Union) is the loss metric here, hence, the bounding box with the highest IoU to the original bounding box target will be accepted.

```
# Example of df[15]
candidates = extract_candidates(im)
print(np.shape(candidates))
print(type(candidates))
show(im, bbs = candidates)
```

```
(38, 4)
<class 'list'>
```



```
help(show)
```

```
Help on function show in module torch_snippets.loader:

show(img=None, ax=None, title=None, sz=None, bbs=None, confs=None, texts=None, bb_col
    show an image
```

np.shape(ds[15])

```
(im, bbs, labels, fpath) = ds[15]
H, W, _ = im.shape
candidates = extract_candidates(im)
candidates = np.array([(x,y,x+w,y+h) for x,y,w,h in candidates])  # candidates extracted

ious, rois, clss, deltas, best_ious = [], [], [], [], []
temp_best_bbs = []
ious = np.array([[extract_iou(candidate, _bb_) for candidate in candidates] for _bb_ in b

for jx, candidate in enumerate(candidates):
    cx,cy,cX,cY = candidate
    candidate_ious = ious[jx]  #ious for that candidate
    best_iou_at = np.argmax(candidate_ious)  #best candidate iou is taken (index) ~ alway
    best_iou = candidate_ious[best_iou_at]   #gets the best score here
    best_ious.append(best_iou)
    best_bb = _x,_y,_X,_Y = bbs[best_iou_at] # gets the target label bounding box where t
    temp_best_bbs.append(best_bb)
    if best_iou > 0.3: clss.append(labels[best_iou_at]) # if iou is more than 0.3 it is n
    else : clss.append('background')
    delta = np.array([_x-cx, _y-cy, _X-cX, _Y-cY]) / np.array([W,H,W,H])  #normalizing th
    deltas.append(delta)
    rois.append(candidate / np.array([W,H,W,H]))

best_ious_at = np.argmax(best_ious)
print("Best IoU:", best_ious[best_ious_at])


best_candidate = candidates[best_ious_at]
best_bbs = temp_best_bbs[best_ious_at]

# Example of df[15]
candidates = extract_candidates(im)
show(im, bbs = [best_bbs, best_candidate], confs= [0,0.5], texts = ['Bbox', 'Best candida
```

```
Best IoU: 0.14555256036666817
```

```
FPATHS, GTBBS, CLSS, DELTAS, ROIS, IOUS = [], [], [], [], [], []
N = 500
for ix, (im, bbs, labels, fpath) in enumerate(ds):
    if(ix==N):
        break
    H, W, _ = im.shape
    candidates = extract_candidates(im)
    candidates = np.array([(x,y,x+w,y+h) for x,y,w,h in candidates])
    ious, rois, clss, deltas = [], [], [], []
    ious = np.array([[extract_iou(candidate, _bb_) for candidate in candidates] for _bb_
    for jx, candidate in enumerate(candidates):
        cx,cy,cX,cY = candidate
        candidate_ious = ious[jx]
        best_iou_at = np.argmax(candidate_ious)
        best_iou = candidate_ious[best_iou_at]
        best_bb = _x,_y,_X,_Y = bbs[best_iou_at]
        # if iou is more than 0.3 it is not the background
        if best_iou > 0.3: clss.append(labels[best_iou_at])
        else : clss.append('background')
        delta = np.array([_x-cx, _y-cy, _X-cX, _Y-cY]) / np.array([W,H,W,H])
        deltas.append(delta)
        rois.append(candidate / np.array([W,H,W,H]))
    FPATHS.append(fpath)
    IOUS.append(ious)
    ROIS.append(rois)
    CLSS.append(clss)
    DELTAS.append(deltas)
    GTBBS.append(bbs)
FPATHS = [f'{IMAGE_ROOT}/{stem(f)}.jpg' for f in FPATHS]
FPATHS, GTBBS, CLSS, DELTAS, ROIS = [item for item in [FPATHS, GTBBS, CLSS, DELTAS, ROIS]


targets = pd.DataFrame(flatten(CLSS), columns=['label'])
label2target = {l:t for t,l in enumerate(targets['label'].unique())}
target2label = {t:l for l,t in label2target.items()}
background_class = label2target['background']
```

```
print("The label to target values dictionary formed is:" ,label2target)
```

```
The label to target values dictionary formed is:
{'Bus': 0, 'background': 1, 'Truck': 2}
```

```
# normalizing with the mean, std used while training the model
normalize = transforms.Normalize(mean=[0.485, 0.456, 0.406],
                                 std=[0.229, 0.224, 0.225])
def preprocess_image(img):
    img = torch.tensor(img).permute(2,0,1)
    img = normalize(img)
    return img.to(device).float()
def decode(_y):
    _, preds = _y.max(-1)
    return preds



class RCNNDataset(Dataset):
    def __init__(self, fpaths, rois, labels, deltas, gtbbs):
        self.fpaths = fpaths
        self.gtbbs = gtbbs
        self.rois = rois
        self.labels = labels
        self.deltas = deltas
    def __len__(self): return len(self.fpaths)
    def __getitem__(self, ix):
        fpath = str(self.fpaths[ix])
        image = cv2.imread(fpath, 1)[...,::-1]
        H, W, _ = image.shape
        sh = np.array([W,H,W,H])
        gtbbs = self.gtbbs[ix]
        rois = self.rois[ix]
        bbs = (np.array(rois)*sh).astype(np.uint16)
        labels = self.labels[ix]
        deltas = self.deltas[ix]
        crops = [image[y:Y,x:X] for (x,y,X,Y) in bbs]  # bounding box image crops
        return image, crops, bbs, labels, deltas, gtbbs, fpath
    def collate_fn(self, batch):
        '''Performing actions on a batch of images'''
        input, rois, rixs, labels, deltas = [], [], [], [], []
        for ix in range(len(batch)):
            image, crops, image_bbs, image_labels, image_deltas, image_gt_bbs, image_fpat
            crops = [cv2.resize(crop, (224,224)) for crop in crops]
            crops = [preprocess_image(crop/255.)[None] for crop in crops]
            input.extend(crops)
            labels.extend([label2target[c] for c in image_labels])
            deltas.extend(image_deltas)
        input = torch.cat(input).to(device)
        labels = torch.Tensor(labels).long().to(device)
        deltas = torch.Tensor(deltas).float().to(device)
        return input, labels, deltas
```

```
n_train = 9*len(FPATHS)//10 # 0.9 is the train size
train_ds = RCNNDataset(FPATHS[:n_train], ROIS[:n_train], CLSS[:n_train], DELTAS[:n_train]
test_ds = RCNNDataset(FPATHS[n_train:], ROIS[n_train:], CLSS[n_train:], DELTAS[n_train:],

from torch.utils.data import TensorDataset, DataLoader
train_loader = DataLoader(train_ds, batch_size=2, collate_fn=train_ds.collate_fn, drop_la
test_loader = DataLoader(test_ds, batch_size=2, collate_fn=test_ds.collate_fn, drop_last=


vgg_backbone = models.vgg16(pretrained=True)
vgg_backbone.classifier = nn.Sequential()
for param in vgg_backbone.parameters():
    param.requires_grad = False #not to do a re-train
vgg_backbone.eval().to(device)
```

```
/usr/local/lib/python3.10/dist-packages/torchvision/models/_utils.py:208: UserWarning
  warnings.warn(
/usr/local/lib/python3.10/dist-packages/torchvision/models/_utils.py:223: UserWarning
  warnings.warn(msg)
Downloading: "https://download.pytorch.org/models/vgg16-397923af.pth" to /root/.cache
100%|██████████| 528M/528M [00:07<00:00, 69.6MB/s]
VGG(
  (features): Sequential(
    (0): Conv2d(3, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (1): ReLU(inplace=True)
    (2): Conv2d(64, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (3): ReLU(inplace=True)
    (4): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1, ceil_mode=False)
    (5): Conv2d(64, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (6): ReLU(inplace=True)
    (7): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (8): ReLU(inplace=True)
    (9): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1, ceil_mode=False)
    (10): Conv2d(128, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (11): ReLU(inplace=True)
    (12): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (13): ReLU(inplace=True)
    (14): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (15): ReLU(inplace=True)
    (16): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1, ceil_mode=False)
    (17): Conv2d(256, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (18): ReLU(inplace=True)
    (19): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (20): ReLU(inplace=True)
    (21): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (22): ReLU(inplace=True)
    (23): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1, ceil_mode=False)
    (24): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (25): ReLU(inplace=True)
    (26): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (27): ReLU(inplace=True)
    (28): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (29): ReLU(inplace=True)
    (30): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1, ceil_mode=False)
  )
  (avgpool): AdaptiveAvgPool2d(output_size=(7, 7))
  (classifier): Sequential()
)
```

```
class RCNN(nn.Module):
    def __init__(self):
        super().__init__()
        feature_dim = 25088
        self.backbone = vgg_backbone
        self.cls_score = nn.Linear(feature_dim, len(label2target))
        self.bbox = nn.Sequential(
              nn.Linear(feature_dim, 512),
              nn.ReLU(),
              nn.Linear(512, 4),
              nn.Tanh(),
            )
        self.cel = nn.CrossEntropyLoss() # loss for classification
        self.sl1 = nn.L1Loss() # loss for regression
    def forward(self, input):
        feat = self.backbone(input)  # both classification and regression takes 'feat' as
        cls_score = self.cls_score(feat)
        bbox = self.bbox(feat)
        return cls_score, bbox
    def calc_loss(self, probs, _deltas, labels, deltas):
        # probs is basically the predicted class
        detection_loss = self.cel(probs, labels)
        ixs, = torch.where(labels != 1) #removing the label 1, which is background
        _deltas = _deltas[ixs]
        deltas = deltas[ixs]
        self.lmb = 10.0
        if len(ixs) > 0:
            regression_loss = self.sl1(_deltas, deltas)
            return detection_loss + self.lmb * regression_loss, detection_loss.detach(),
        else:
            # every ix is detected as background
            regression_loss = 0
            return detection_loss + self.lmb * regression_loss, detection_loss.detach(),


def train_batch(inputs, model, optimizer, criterion):
    input, clss, deltas = inputs
    model.train()
    optimizer.zero_grad()
    _clss, _deltas = model(input)  # as model outputs we will be getting classes and delt
    loss, loc_loss, regr_loss = criterion(_clss, _deltas, clss, deltas)
    accs = clss == decode(_clss)
    loss.backward()
    optimizer.step()
    return loss.detach(), loc_loss, regr_loss, accs.cpu().numpy()
```

```
@torch.no_grad()
def validate_batch(inputs, model, criterion):
    input, clss, deltas = inputs
    with torch.no_grad():
        model.eval()

rcnn = RCNN().to(device)
criterion = rcnn.calc_loss
optimizer = optim.SGD(rcnn.parameters(), lr=1e-3)
n_epochs = 5
log = Report(n_epochs) #records the metrics as report, can be used to plot later


# loc_loss: loss on classification
# regr_loss: loss on regression

for epoch in range(n_epochs):

    _n = len(train_loader)
    for ix, inputs in enumerate(train_loader):
        loss, loc_loss, regr_loss, accs = train_batch(inputs, rcnn,
                                                      optimizer, criterion)
        pos = (epoch + (ix+1)/_n)
        log.record(pos, trn_loss=loss.item(), trn_loc_loss=loc_loss,
                   trn_regr_loss=regr_loss,
                   trn_acc=accs.mean(), end='\r')

    _n = len(test_loader)
    for ix,inputs in enumerate(test_loader):
        _clss, _deltas, loss, \
```