14.7 Single Shot Multibox Detection (SSD)

```
!pip install d2l==1.0.0-alpha1.post0
```

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Installing collected packages: qtpy, jedi, qtconsole, jupyter, d2l
Successfully installed d2l-1.0.0a1.post0 jedi-0.19.1 jupyter-1.0.0 qtconsole-5.5.1 qtpy-2.4.1
```

```
%matplotlib inline
import torch
import torchvision
from torch import nn
from torch.nn import functional as F
from d2l import torch as d2l


def cls_predictor(num_inputs, num_anchors, num_classes):
    return nn.Conv2d(num_inputs, num_anchors * (num_classes + 1),
                     kernel_size=3, padding=1)
```

```
def bbox_predictor(num_inputs, num_anchors):
    return nn.Conv2d(num_inputs, num_anchors * 4, kernel_size=3, padding=1)
```

```
def forward(x, block):
    return block(x)

Y1 = forward(torch.zeros((2, 8, 20, 20)), cls_predictor(8, 5, 10))
```

```
Y2 = forward(torch.zeros((2, 16, 10, 10)), cls_predictor(16, 3, 10))
Y1.shape, Y2.shape
```

```
(torch.Size([2, 55, 20, 20]), torch.Size([2, 33, 10, 10]))
```

```
def flatten_pred(pred):
    return torch.flatten(pred.permute(0, 2, 3, 1), start_dim=1)

def concat_preds(preds):
    return torch.cat([flatten_pred(p) for p in preds], dim=1)
```

```
concat_preds([Y1, Y2]).shape
```

```
torch.Size([2, 25300])
```

```
def down_sample_blk(in_channels, out_channels):
    blk = []
    for _ in range(2):
        blk.append(nn.Conv2d(in_channels, out_channels,
                             kernel_size=3, padding=1))
        blk.append(nn.BatchNorm2d(out_channels))
        blk.append(nn.ReLU())
        in_channels = out_channels
    blk.append(nn.MaxPool2d(2))
    return nn.Sequential(*blk)
```

```
forward(torch.zeros((2, 3, 20, 20)), down_sample_blk(3, 10)).shape
```

```
torch.Size([2, 10, 10, 10])
```

```
def base_net():
    blk = []
    num_filters = [3, 16, 32, 64]
    for i in range(len(num_filters) - 1):
        blk.append(down_sample_blk(num_filters[i], num_filters[i+1]))
    return nn.Sequential(*blk)

forward(torch.zeros((2, 3, 256, 256)), base_net()).shape
```

```
torch.Size([2, 64, 32, 32])
```

```
def get_blk(i):
    if i == 0:
        blk = base_net()
    elif i == 1:
        blk = down_sample_blk(64, 128)
    elif i == 4:
        blk = nn.AdaptiveMaxPool2d((1,1))
    else:
        blk = down_sample_blk(128, 128)
    return blk
```

```
def blk_forward(X, blk, size, ratio, cls_predictor, bbox_predictor):
    Y = blk(X)
    anchors = d2l.multibox_prior(Y, sizes=size, ratios=ratio)
    cls_preds = cls_predictor(Y)
    bbox_preds = bbox_predictor(Y)
    return (Y, anchors, cls_preds, bbox_preds)
```

```
sizes = [[0.2, 0.272], [0.37, 0.447], [0.54, 0.619], [0.71, 0.79],
         [0.88, 0.961]]
ratios = [[1, 2, 0.5]] * 5
num_anchors = len(sizes[0]) + len(ratios[0]) - 1
```

```
class TinySSD(nn.Module):
    def __init__(self, num_classes, **kwargs):
        super(TinySSD, self).__init__(**kwargs)
        self.num_classes = num_classes
        idx_to_in_channels = [64, 128, 128, 128, 128]
        for i in range(5):
            # Equivalent to the assignment statement `self.blk_i = get_blk(i)`
            setattr(self, f'blk_{i}', get_blk(i))
            setattr(self, f'cls_{i}', cls_predictor(idx_to_in_channels[i],
                                                    num_anchors, num_classes))
            setattr(self, f'bbox_{i}', bbox_predictor(idx_to_in_channels[i],
                                                      num_anchors))

    def forward(self, X):
```

```
    def forward(self, X):
        anchors, cls_preds, bbox_preds = [None] * 5, [None] * 5, [None] * 5
        for i in range(5):
            # Here `getattr(self, 'blk_%d' % i)` accesses `self.blk_i`
            X, anchors[i], cls_preds[i], bbox_preds[i] = blk_forward(
                X, getattr(self, f'blk_{i}'), sizes[i], ratios[i],
                getattr(self, f'cls_{i}'), getattr(self, f'bbox_{i}'))
        anchors = torch.cat(anchors, dim=1)
        cls_preds = concat_preds(cls_preds)
        cls_preds = cls_preds.reshape(
            cls_preds.shape[0], -1, self.num_classes + 1)
        bbox_preds = concat_preds(bbox_preds)
        return anchors, cls_preds, bbox_preds
```

```
net = TinySSD(num_classes=1)
X = torch.zeros((32, 3, 256, 256))
anchors, cls_preds, bbox_preds = net(X)

print('output anchors:', anchors.shape)
print('output class preds:', cls_preds.shape)
print('output bbox preds:', bbox_preds.shape)
```

```
output anchors: torch.Size([1, 5444, 4])
output class preds: torch.Size([32, 5444, 2])
output bbox preds: torch.Size([32, 21776])
```

```
batch_size = 32
train_iter, _ = d2l.load_data_bananas(batch_size)
```

```
Downloading ../data/banana-detection.zip from http://d2l-data.s3-accelerate.amazonaws.com/banana-detection.zip...
read 1000 training examples
read 100 validation examples
```

```
device, net = d2l.try_gpu(), TinySSD(num_classes=1)
trainer = torch.optim.SGD(net.parameters(), lr=0.2, weight_decay=5e-4)
```

```
cls_loss = nn.CrossEntropyLoss(reduction='none')
bbox_loss = nn.L1Loss(reduction='none')

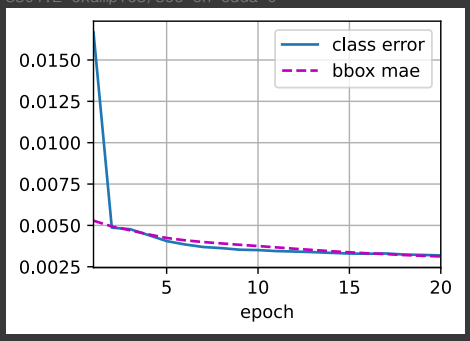
def calc_loss(cls_preds, cls_labels, bbox_preds, bbox_labels, bbox_masks):
    batch_size, num_classes = cls_preds.shape[0], cls_preds.shape[2]
    cls = cls_loss(cls_preds.reshape(-1, num_classes),
                   cls_labels.reshape(-1)).reshape(batch_size, -1).mean(dim=1)
    bbox = bbox_loss(bbox_preds * bbox_masks,
                     bbox_labels * bbox_masks).mean(dim=1)
    return cls + bbox
```

```
def cls_eval(cls_preds, cls_labels):
    # Because the class prediction results are on the final dimension,
    # `argmax` needs to specify this dimension
    return float((cls_preds.argmax(dim=-1).type(
        cls_labels.dtype) == cls_labels).sum())

def bbox_eval(bbox_preds, bbox_labels, bbox_masks):
    return float((torch.abs((bbox_labels - bbox_preds) * bbox_masks)).sum())
```

```
num_epochs, timer = 20, d2l.Timer()
animator = d2l.Animator(xlabel='epoch', xlim=[1, num_epochs],
                        legend=['class error', 'bbox mae'])
net = net.to(device)
for epoch in range(num_epochs):
    # Sum of training accuracy, no. of examples in sum of training accuracy,
    # Sum of absolute error, no. of examples in sum of absolute error
    metric = d2l.Accumulator(4)
    net.train()
    for features, target in train_iter:
        timer.start()
        trainer.zero_grad()
        X, Y = features.to(device), target.to(device)
        # Generate multiscale anchor boxes and predict their classes and
        # offsets
        anchors, cls_preds, bbox_preds = net(X)
        # Label the classes and offsets of these anchor boxes
        bbox_labels, bbox_masks, cls_labels = d2l.multibox_target(anchors, Y)
        # Calculate the loss function using the predicted and labeled values
        # of the classes and offsets
        l = calc_loss(cls_preds, cls_labels, bbox_preds, bbox_labels,
                      bbox_masks)
        l.mean().backward()
        trainer.step()
        metric.add(cls_eval(cls_preds, cls_labels), cls_labels.numel(),
                   bbox_eval(bbox_preds, bbox_labels, bbox_masks),
                   bbox_labels.numel())
    cls_err, bbox_mae = 1 - metric[0] / metric[1], metric[2] / metric[3]
    animator.add(epoch + 1, (cls_err, bbox_mae))
print(f'class err {cls_err:.2e}, bbox mae {bbox_mae:.2e}')
print(f'{len(train_iter.dataset) / timer.stop():.1f} examples/sec on '
      f'{str(device)}')
```

```
class err 3.19e-03, bbox mae 3.12e-03
5501.2 examples/sec on cuda:0
```



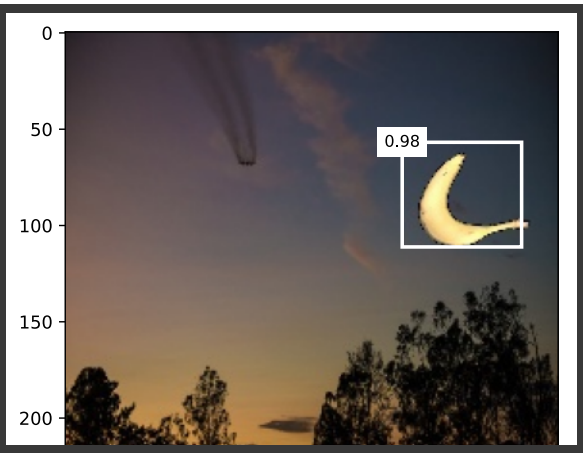

```
X = torchvision.io.read_image('../data/banana-detection/bananas_val/images/0.png').unsqueeze(0).float() # 경로 임의 수정
img = X.squeeze(0).permute(1, 2, 0).long()
```

```
def predict(X):
    net.eval()
    anchors, cls_preds, bbox_preds = net(X.to(device))
    cls_probs = F.softmax(cls_preds, dim=2).permute(0, 2, 1)
    output = d2l.multibox_detection(cls_probs, bbox_preds, anchors)
    idx = [i for i, row in enumerate(output[0]) if row[0] != -1]
    return output[0, idx]

output = predict(X)
```

```
def display(img, output, threshold):
    d2l.set_figsize((5, 5))
    fig = d2l.plt.imshow(img)
    for row in output:
        score = float(row[1])
        if score < threshold:
            continue
        h, w = img.shape[:2]
        bbox = [row[2:6] * torch.tensor((w, h, w, h), device=row.device)]
        d2l.show_bboxes(fig.axes, bbox, '%.2f' % score, 'w')

display(img, output.cpu(), threshold=0.9)
```



14.3 Object Detection and Bounding Boxes

Reading:

1. Object Detection은 여러 개의 object들에 대해서 category 뿐만 아니라 position을 recognize한다.
2. Bounding Box를 나타내는 두가지 방법
    - (upper-left, lower-right)
    - (center, width, height)

14.4 Anchor Boxes

Reading:

1. 여러 개의 anchor box들을 만들 수 있는 모든 경우의 수는 whnm(w는 width, h는 height, n은 가능한 scale의 개수, m은 가능한 aspect ratio의 개수)개 이다. 그러나 이것은 너무 크기에 scale을 첫 번째로 고정하고 aspect ratio만 변경하거나, aspect ratio를 첫 번째로 고정하고 scale만 변경하는 방법을 선택한다. 이 경우에 가능한 조합의 수는 wh(n+m-1)개 이다.
2. ground-truth bounding box를 알 때 Jaccard index를 이용하여 anchor box가 얼마나 object를 잘 둘러싸고 있는지 평가할 수 있다. 두 개의 bounding box의 경우 둘의 Jaccrd index를 intersection over union(IoU)라고 할 수 있다. IoU는 union area에 대한 intersection area의 비율이다.IoU의 범위는 0에서 1 사이이다. 0은 완전히 일치하지 않음을, 1은 완전히 일치함을 의미한다.
3. Object detectionmodel을 train하기 위해서는 각각의 anchor box들에 대해서 anchor box와 relative한 object의 class와 anchor box와 relative한 ground-truth bounding box와의 offset이 필요하다.
4. Training Data로 Anchor Box들에 Labeling하는 과정

    (1) Ground-Truth Bounding Box들을 Anchor Box들에 Assign

    (2) 각각의 anchor box들에 대해서 Class들과 Offset들을 Labeling
5. Non-maximum suppression(NMS)를 통해 어떤 object에 해당하는 비슷한 예측된 bounding box들을 하나로 통일하여 output을 간단하게 나타낼 수 있다.