Concise Implementation of RNNs

- Here we will see how to implement the same language model more efficiently using functions provided by Pytorch.

Loading the Dataset

In [231]:
```
batch_size, num_steps = 32, 35
train_iter, vocab = mu.load_data_time_machine(batch_size, num_steps)
```

In [232]:
```
print(list(vocab.token_to_idx.items())[:])
```

```
[('<unk>', 0), (' ', 1), ('e', 2), ('t', 3), ('a', 4), ('i', 5), ('n', 6),
('o', 7), ('s', 8), ('h', 9), ('r', 10), ('d', 11), ('l', 12), ('m', 13),
('u', 14), ('c', 15), ('f', 16), ('w', 17), ('g', 18), ('y', 19), ('p', 20),
('b', 21), ('v', 22), ('k', 23), ('x', 24), ('z', 25), ('j', 26), ('q', 27)]
```

In [233]:
```
train_iterator = iter(train_iter)
```

In [234]:
```
batch_1 = next(train_iterator)
```

In [235]:
```
sample_1 = batch_1[0][1, :]
```

In [236]:
```
sample_1
```

Out[236]:
```
tensor([ 9,  2,  1, 21, 14, 21, 21, 12,  2,  8,  1,  3,  9,  4,  3,  1, 16,
12,
         4,  8,  9,  2, 11,  1,  4,  6, 11, 20,  4,  8,  8,  2, 11,  1,  5])
```

In [237]:
```
sample_token = [vocab.idx_to_token[idx] for idx in sample_1]
print(sample_token)
```

```
['h', 'e', ' ', 'b', 'u', 'b', 'b', 'l', 'e', 's', ' ', 't', 'h', 'a', 't',
' ', 'f', 'l', 'a', 's', 'h', 'e', 'd', ' ', 'a', 'n', 'd', 'p', 'a', 's', '
s', 'e', 'd', ' ', 'i']
```

In [249]:
```
sample_1_y = batch_1[1][1, :]
print(sample_1_y)
```

```
tensor([ 2,  1, 21, 14, 21, 21, 12,  2,  8,  1,  3,  9,  4,  3,  1, 16, 12,
4,
         8,  9,  2, 11,  1,  4,  6, 11, 20,  4,  8,  8,  2, 11,  1,  5,  6])
```

Defining the Model

In [239]:
```
# An RNN with a single hidden layer and 256 hidden units.
num_hiddens = 256
rnn_layer = nn.RNN(input_size = len(vocab), hidden_size= num_hiddens)
```

In [240]:
```
# A tensor is used to initialize the hidden state
state = torch.zeros((1, batch_size, num_hiddens))
state.size() #number of hidden layers x batch size x number of hidden units
```

Out[240]:
```
torch.Size([1, 32, 256])
```

- Given the previous hidden state and an input, we can compute the updated hidden state.
- The "output" (`Y`) of `rnn_layer` refers to the hidden state at *each* time step, not the output of the model.

In [241]:
```
X = torch.rand(num_steps, batch_size, len(vocab))
X.size()
```

Out[241]:
```
torch.Size([35, 32, 28])
```

In [242]:
```
Y, state_new = rnn_layer(X, state)
Y.size(), state_new.size()
```

Out[242]:
```
(torch.Size([35, 32, 256]), torch.Size([1, 32, 256]))
```

In [243]:
```python
# RNNModel class contains a complete RNN model.
# rnn_layer only contains the hidden recurrent layers, we need to create a separat
e output layer.
class RNNModel(nn.Module):
    """The RNN model."""
    def __init__(self, rnn_layer, vocab_size):
        super(RNNModel, self).__init__()
        self.rnn = rnn_layer
        self.vocab_size = vocab_size
        self.num_hiddens = self.rnn.hidden_size
        self.linear = nn.Linear(self.num_hiddens, self.vocab_size)

    def forward(self, inputs, state):
        X = F.one_hot(inputs.T.long(), self.vocab_size)
        X = X.to(torch.float32)
        Y, state = self.rnn(X, state)
        #print(X.size()) # 35x32x28
        #print(Y.size()) # 35x32x256
        #print(state.size()) # 32x256
        Y1 = Y.reshape((-1, Y.shape[-1]))
        #print(Y1.size()) # 1120x256
        out = self.linear(Y1)
        #print(out.size()) # 1120x256
        return out, state

    def begin_state(self, batch_size=1):
        state = torch.zeros((self.rnn.num_layers, batch_size, self.num_hiddens))
        return state
```

Training and Predicting

- Before training the model, let us make a prediction with the a model that has random weights.

In [244]:
```
def predict_ch8(prefix, num_preds, model, vocab):
    """Generate new characters following the `prefix`."""
    state = model.begin_state(batch_size=1)
    outputs = [vocab[prefix[0]]]
    get_input = lambda: mu.reshape(torch.tensor([outputs[-1]]), (1, 1))
    for y in prefix[1:]:  # Warm-up period
        _, state = model(get_input(), state)
        outputs.append(vocab[y])
    for _ in range(num_preds):  # Predict `num_preds` steps
        y, state = model(get_input(), state)
        outputs.append(int(y.argmax(dim=1).reshape(1)))
    return ''.join([vocab.idx_to_token[i] for i in outputs])
```

In [245]:
```
model = RNNModel(rnn_layer, vocab_size=len(vocab))
predict_ch8('time traveller', 10, model, vocab)
```

Out[245]:
```
'time travellerrrrrrrrrr'
```

- Training with `train_ch8` with the same hyperparameters as before

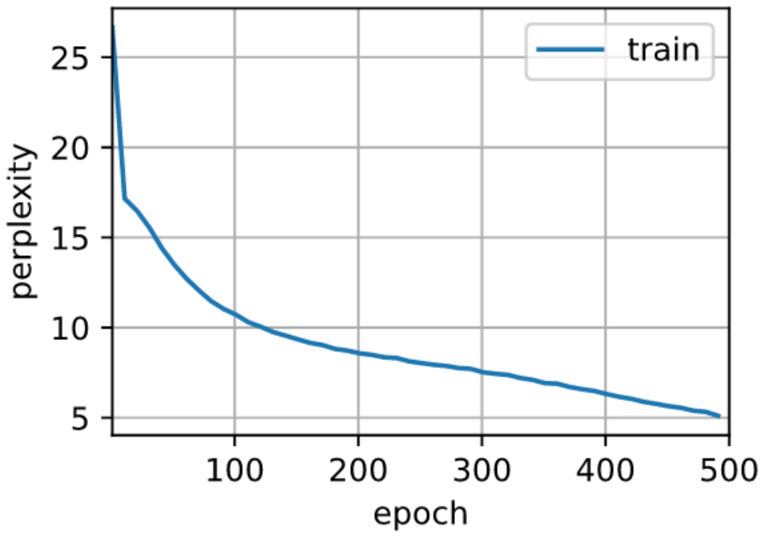
In [255]:
```
def train_epoch_ch8(model, train_iter, loss, optimizer, use_random_iter):
    """Train a model for one epoch """
    state = None
    metric = mu.Accumulator(2)  # Sum of training loss, no. of tokens
    for X, Y in train_iter:
        # Initialize `state` when first iteration or using random sampling
        if state is None or use_random_iter:
            state = model.begin_state(batch_size=X.shape[0])
        #print(X.size(), Y.size(), state.size()) # 32x35, 32x35, 32x256
        y = Y.T.reshape(-1)
        #print(y.size()) # 35x32 -> 1120
        y_hat, state = model(X, state)
        #print(y_hat.size()) # 1120x28
        l = loss(y_hat, y.long())
        optimizer.zero_grad()
        l.backward()
        mu.grad_clipping(model, 1)
        optimizer.step()

        metric.add(l * mu.size(y), mu.size(y))
    return math.exp(metric[0] / metric[1])
```

In [247]:

```
def train_ch8(model, train_iter, vocab, lr, num_epochs, use_random_iter=False):
    """Train a model for num_epochs"""
    animator = mu.Animator(xlabel='epoch', ylabel='perplexity', legend=['train'],
xlim=[1, num_epochs])
    loss = nn.CrossEntropyLoss()
    optimizer = torch.optim.SGD(model.parameters(), lr)
    # Train and predict
    for epoch in range(num_epochs):
        ppl = train_epoch_ch8(model, train_iter, loss, optimizer, use_random_iter)
        if epoch % 10 == 0:
            print(predict_ch8('time traveller', 50, model, vocab))
            animator.add(epoch + 1, [ppl])
    print(f'perplexity {ppl:.1f}')
    print(predict_ch8('time traveller', 50, model, vocab))
    print(predict_ch8('traveller', 50, model, vocab))
```

In [248]:
```
num_epochs, lr = 500, 0.1
train_ch8(model, train_iter, vocab, lr, num_epochs, device)
```

```
perplexity 5.0
time traveller sithe fore than souren this time someraid the tim
traveller ait said the time traveller  it t andins ant mere
```



Summary

- PyTorch provides an implementation of the RNN layer.
- The RNN layer of PyTorch returns an output and an updated hidden state, where the output does not involve output layer computation.