FAST.AI LESSON 6 REVIEW

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SOME CHANGES TO JEREMY'S CODE

Migrated from Keras 1 to 2

Migrated from Python 2 to 3

Using a Tensorflow backend (instead of Theano)

Only important difference: Had to remove extra dimensions for some training

USE CASES FOR RNNS

- Anything that requires knowledge of long term structure
- Text data
- Sequential data
- Time series

THREE CHARACTER MODEL

MAPPING CHARACTERS TO INTEGERS

```
char_indices = dict((c, i) for i, c in enumerate(chars))
indices_char = dict((i, c) for i, c in enumerate(chars))
```

INPUTS AND OUTPUT

```
cs=3
c1_dat = [idx[i] for i in range(0, len(idx)-1-cs, cs)]
c2_dat = [idx[i+1] for i in range(0, len(idx)-1-cs, cs)]
c3_dat = [idx[i+2] for i in range(0, len(idx)-1-cs, cs)]
c4_dat = [idx[i+3] for i in range(0, len(idx)-1-cs, cs)]
```

This creates a list of numbers.

We need a matrix. So we create an embedding

EMBEDDING

n_fac is a hyperparameter

```
def embedding_input(name, n_in, n_out):
    inp = Input(shape=(1,), dtype='int64', name=name)
    emb = Embedding(n_in, n_out, input_length=1)(inp)
    return inp, Flatten()(emb)
```

Parameters: 3570

INPUT TO HIDDEN LAYER

```
n_hidden = 256
dense_in = Dense(n_hidden, activation='relu')
c1_hidden = dense_in(c1)
```

Parameters: 11008

HIDDEN TO HIDDEN LAYER

```
from keras.layers.merge import add as merge_add
dense_hidden = Dense(n_hidden, activation='relu')
c2_dense = dense_in(c2)
hidden_2 = dense_hidden(c1_hidden)
c2_hidden = merge_add([c2_dense, hidden_2])  # Element-wise sum
```

Parameters: 65792

HIDDEN TO OUTPUT LAYER

```
c3_dense = dense_in(c3)
hidden_3 = dense_hidden(c2_hidden)
c3_hidden = merge_add([c3_dense, hidden_3])
dense_out = Dense(vocab_size, activation='softmax')
c4_out = dense_out(c3_hidden)
```

Parameters: 21845

NTH CHARACTER MODEL

RNN FORMS:

1. Unrolled Form (previous example)
2. Recurrent Form (next example)

Note: Jeremy mentioned that Tensorflow does not have the ability to make recurrent form RNNs.

This is no longer true. Use `tf.nn.dynamic_rnn`.

```
dense_in = Dense(n_hidden, activation='relu')
dense_hidden = Dense(n_hidden, activation='relu',
                     kernel_initializer="identity")
dense_out = Dense(vocab_size, activation='softmax')
```

COMBINING LAYERS

```
hidden = dense_in(c_ins[0][1])
for i in range(1,cs):
    c_dense = dense_in(c_ins[i][1])
    hidden = dense_hidden(hidden)
    hidden = merge_add([c_dense, hidden])
c_out = dense_out(hidden)
```

This is common architecture. So Keras already has a version of it.

KERAS: SIMPLERNN

```
model=Sequential([
        Embedding(vocab_size, n_fac, input_length=cs),
        SimpleRNN(n_hidden, activation='relu',
                  recurrent_initializer='identity'),
        Dense(vocab_size, activation='softmax')
    ])
```

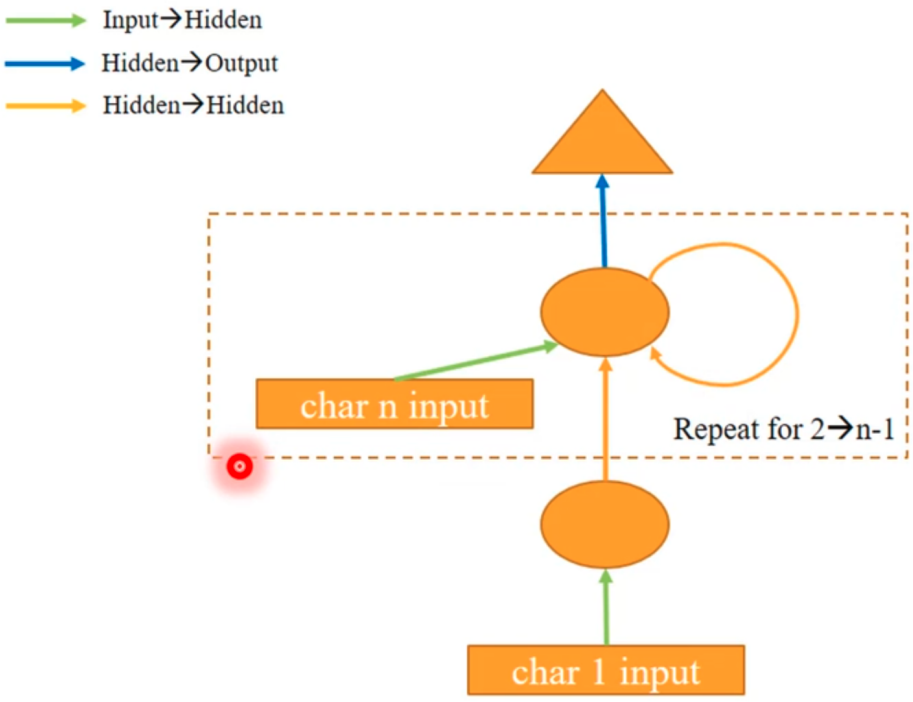
By setting recurrent_initializer = identity means do nothing by default

Parameters of Dense layer: 22102

Parameters of SimpleRNN: 76544

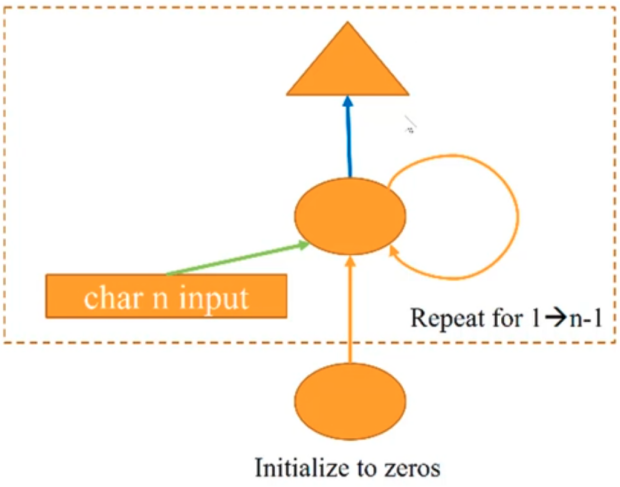
SEQUENTIAL RNNS

Predicting char n using chars 1 to n-1



NOW

Predicting chars 2 to n using chars 1 to n-1



The output of one step is the input of the next step

```
c_in_dat = [[idx[i+n] for i in range(0, len(idx) - 1 - cs, cs)]
            for n in range(cs)]
c_out_dat = [[idx[i+n] for i in range(1, len(idx) - cs, cs)]
            for n in range(cs)] # This changed
```

THE INPUT ALSO CHANGES

```
inp1 = Input(shape=(n_fac,), name='zeros')
hidden = dense_in(inp1)
```

```
outs = []

for i in range(cs):
    c_dense = dense_in(c_ins[i][1])
    hidden = dense_hidden(hidden)
    hidden = merge_add([c_dense, hidden], mode='sum')
    # every layer now has an output
    outs.append(dense_out(hidden))
```

Eight outputs means eight binary cross entropies to manage

THIS IS EASY IN KERAS

```
model=Sequential([
        Embedding(vocab_size, n_fac, input_length=cs),
        SimpleRNN(n_hidden,
                  return_sequences=True,
                  activation='relu',
                  recurrent_initializer='identity'),
        TimeDistributed(Dense(vocab_size, activation='softmax')),
    ])
```

Two differences

1. return_sequences=True
2. TimeDistributed wrapped around Dense

STATEFUL RNNS

FIRST MODEL

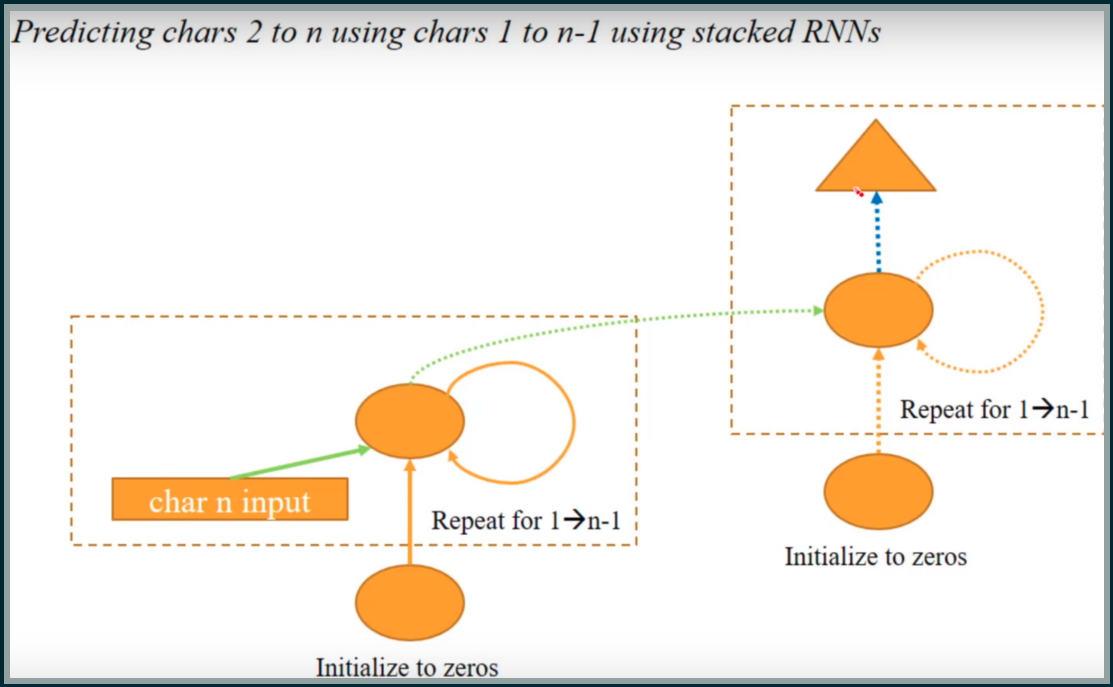
```
model=Sequential([
        Embedding(vocab_size, n_fac, input_length=cs,
                  batch_input_shape=(bs, 8)),
        BatchNormalization(),
        LSTM(n_hidden, return_sequences=True, stateful=True),
        TimeDistributed(Dense(vocab_size, activation='softmax')),
    ])
```

Batch Normalization was required to get this model running

BatchNorm Parameters: 168

LSTM Parameters: 306176

STACKED RNN


Predicting chars 2 to n using chars 1 to n-1 using stacked RNNs
char n input
Repeat for 1→n-1
Initialize to zeros
Repeat for 1→n-1
Initialize to zeros

```
model=Sequential([
        Embedding(vocab_size, n_fac, input_length=maxlen),
        LSTM(512, recurrent_dropout=0.2, return_sequences=True,
             dropout=0.2, implementation=2, input_shape=(n_fac,))
        Dropout(0.2),
        LSTM(512, dropout=0.2, recurrent_dropout=0.2,
             return_sequences=True),
        Dropout(0.2),
        TimeDistributed(Dense(vocab_size)),
        Activation('softmax')
    ])
```

This will take a long time to train but gives the best results we've seen so far

THEANO RNN

Sparse Categorical Cross-entropy just converts integer to a one-hot encoding implicitly

We to make this explicit for Theano

```
model=Sequential([
        SimpleRNN(n_hidden, return_sequences=True,
                  input_shape=(cs, vocab_size),
                  activation='relu',
                  recurrent_initializer="identity"),
        TimeDistributed(Dense(vocab_size, activation='softmax')),
    ])
model.compile(loss='categorical_crossentropy', optimizer=Adam())
```

THEANO

- Manipulates tensors in the GPU
- Automatic Differentiation
- Need to declare upfront for computational graph
- Used shared to claim an array for theano
- Breaks CUDA when you try upgrade it the day before a presentation

INITIALIZATION

```
def init_wgts(rows, cols):
    scale = math.sqrt(2 / rows)
    return shared(normal(scale=scale,
                         size=(rows, cols)).astype(np.float32))
def init_bias(rows):
    return shared(np.zeros(rows, dtype=np.float32))
```

INITIALIZATION

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def init_wgts(rows, cols):
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                         size=(rows, cols)).astype(np.float32))

def init_bias(rows):
    return shared(np.zeros(rows, dtype=np.float32))

def wgts_and_bias(n_in, n_out):
    return init_wgts(n_in, n_out), init_bias(n_out)

def id_and_bias(n):
    return shared(np.eye(n, dtype=np.float32)), init_bias(n)
```

ANNOUNCING TO THEANO

```
t_inp = T.matrix('inp', dtype="float32")
t_outp = T.matrix('outp', dtype="float32")
t_h0 = T.vector('h0', dtype="float32")
lr = T.scalar('lr', dtype="float32")

all_args = [t_h0, t_inp, t_outp, lr]

W_h = id_and_bias(n_hidden)               # Hidden-to-hidden
W_x = wgts_and_bias(n_input, n_hidden)  # Input-to-hidden
W_y = wgts_and_bias(n_hidden, n_output) # Hidden-to-output
w_all = list(chain.from_iterable([W_h, W_x, W_y]))
```

SCANNING

```
def step(x, h, W_h, b_h, W_x, b_x, W_y, b_y):
    # Calculate the hidden activations
    h = nnet.relu(T.dot(x, W_x) + b_x + T.dot(h, W_h) + b_h)
    # Calculate the output activations
    y = nnet.softmax(T.dot(h, W_y) + b_y)
    # Return both (the 'Flatten()' is to work around a theano bug
    return h, T.flatten(y, 1)

[v_h, v_y], _ = theano.scan(step, sequences=t_inp,
                            outputs_info=[t_h0, None],
                            non_sequences=w_all)
```

GRADIENTS

```
error = nnet.categorical_crossentropy(v_y, t_outp).sum()
g_all = T.grad(error, w_all)

def upd_dict(wgts, grads, lr):
    return OrderedDict({w: w - g * lr for (w, g)
                        in zip(wgts, grads)})
                        # This is gradient descent!

upd = upd_dict(w_all, g_all, lr)

fn = theano.function(all_args, error, updates=upd,
                     allow_input_downcast=True)
```

UPDATES

```
err=0.0; l_rate=0.01
for i in range(len(X)):
    err += fn(np.zeros(n_hidden), X[i], Y[i], l_rate)
    if i % 1000 == 999:
        print ("Error:{:.3f}".format(err / 1000))
        err=0.0
```

ANSWERS

```
f_y = theano.function([t_h0, t_inp], v_y,
                      allow_input_downcast=True)

pred = np.argmax(f_y(np.zeros(n_hidden), X[6]), axis=1)
act = np.argmax(X[6], axis=1)

[indices_char[o] for o in act]
[indices_char[o] for o in pred]
```

QUESTIONS?