

```
In [2]: # Canonical way of importing TensorFlow  
import tensorflow as tf  
import numpy as np  
import matplotlib.pyplot as plt  
from sklearn.datasets import load_digits  
digits= load_digits()  
  
# If this doesn't work TensorFlow is not installed correctly  
  
# Check tf version, oftentimes tensorflow is not backwards compatible  
tf.__version__
```

```
Out[2]: '1.4.0'
```

```

In [3]: # TensorBoard Graph visualizer in notebook
from IPython.display import clear_output, Image, display, HTML

def strip_consts(graph_def, max_const_size=32):
    """Strip large constant values from graph_def."""
    strip_def = tf.GraphDef()
    for n0 in graph_def.node:
        n = strip_def.node.add()
        n.MergeFrom(n0)
        if n.op == 'Const':
            tensor = n.attr['value'].tensor
            size = len(tensor.tensor_content)
            if size > max_const_size:
                tensor.tensor_content = "<stripped %d bytes>"%size
    return strip_def

def show_graph(graph_def, max_const_size=32):
    """Visualize TensorFlow graph."""
    if hasattr(graph_def, 'as_graph_def'):
        graph_def = graph_def.as_graph_def()
    strip_def = strip_consts(graph_def, max_const_size=max_const_size)
    code = """
        <script src="//cdnjs.cloudflare.com/ajax/libs/polymer/0.3.3/platform.js"></script>
        <script>
            function load() {{
                document.getElementById("{id}").pbtxt = {data};
            }}
        </script>
        <link rel="import" href="https://tensorboard.appspot.com/tf-graph-basic
c.build.html" onload=load()>
        <div style="height:600px">
            <tf-graph-basic id="{id}"></tf-graph-basic>
        </div>
        """.format(data=repr(str(strip_def)), id='graph'+str(np.random.rand()))

    iframe = """
        <iframe seamless style="width:1200px;height:620px;border:0" srcdoc="{}
"></iframe>
        """.format(code.replace("'", '&quot;'))
    display(HTML(iframe))

```

```
In [4]: # Break up data into train and test
from sklearn.model_selection import train_test_split

digits_target = []
for target in digits.target:
    a = np.zeros(10)
    a[target]=1
    digits_target.append(a.tolist())

# print (digits_target)
x_train, x_test, y_train, y_test = train_test_split(digits.data, digits_target, test_size=0.20, random_state=0)
X_train, X_test, y_train2, y_test2 = train_test_split(digits.data, digits.target, test_size=0.20, random_state=0)

# x_train = tf.Variable(x_train)
# y_train = tf.Variable(y_train)
# x_test = tf.Variable(x_test)
# y_test = tf.Variable(y_test)

# print(x_train, y_train, x_test, y_test)
# x_train.get_shape().as_list()[0]
```

```
In [5]: tf.reset_default_graph()
```

```
In [6]: # Define input
x = tf.placeholder(tf.float32, shape = [None, 64])
# None, because we don't specify how many examples we'll look at

W = tf.Variable(tf.zeros([64, 10])) # number of weights
b = tf.Variable(tf.zeros([10])) # number of bias terms
```

```
In [7]: y_hat = tf.nn.softmax(tf.matmul(x, W) + b)
# define what we'll take the softmax activation on

# Notice order on x and W (dimensions must match)
```

```
In [8]: # correct answers

# y = tf.placeholder(tf.float32, [None, 10])

y = tf.placeholder(tf.float32, [None, 10])
```

```
In [9]: # define loss function
# Cross entropy

ce = tf.reduce_mean(-tf.reduce_sum(y * tf.log(y_hat), axis=1))
```

```
In [10]: ce # sum over the columns to get cost for every training example
```

```
Out[10]: <tf.Tensor 'Mean:0' shape=() dtype=float32>
```

```
In [11]: train_step = tf.train.GradientDescentOptimizer(learning_rate = .001).minimize(
ce)
```

```
In [12]: def acc_train(x_train, y_train):
    correct_prediction = tf.equal(tf.argmax(y,1), tf.argmax(y_hat,1))
    accuracy = tf.reduce_mean(tf.cast(correct_prediction, tf.float32))
    a = sess.run(accuracy, feed_dict={x: x_train, y: y_train})
    # print(a)
    return a

# monitor accuracy
def acc():
    correct_prediction = tf.equal(tf.argmax(y,1), tf.argmax(y_hat,1))
    accuracy = tf.reduce_mean(tf.cast(correct_prediction, tf.float32))
    a = sess.run(accuracy, feed_dict={x: x_test, y: y_test})
    # print(a)
    return a
```

```
In [13]: sess = tf.Session()
```

```
In [14]: sess.run(tf.global_variables_initializer())
```

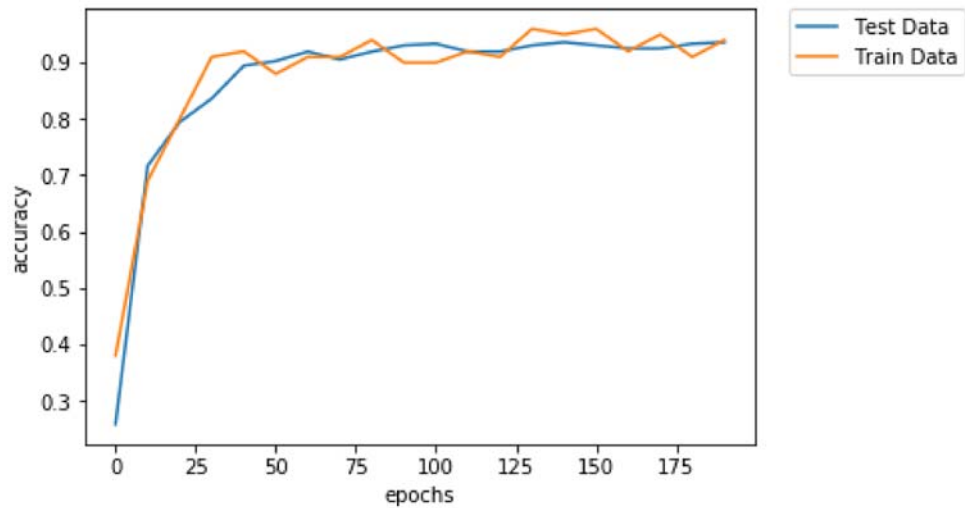
```
In [15]: def next_batch(num, data, labels):
    """
    Return a total of `num` random samples and labels.
    """
    idx = np.arange(0 , len(data))
    # idx = np.arange(0, data.get_shape().as_list()[0])
    np.random.shuffle(idx)
    idx = idx[:num]
    data_shuffle = [data[ i] for i in idx]
    labels_shuffle = [labels[ i] for i in idx]

    return np.asarray(data_shuffle), np.asarray(labels_shuffle)
```

```
In [16]: accr_train = []
accr = []
epochs = []

for i in range(200):
    # get batches of training data
    # we don't show everything to the network at once
    # batch_xs = x_train.next_batch(100)
    # batch_ys = y_train.next_batch(100)
    batch_xs, batch_ys = next_batch(100, x_train, y_train)
    # print(batch_xs)
    sess.run(train_step, feed_dict={x: batch_xs, y: batch_ys})
    if i%10==0:
    # acc()
        accr_train.append(acc_train(batch_xs, batch_ys))
        accr.append(acc())
        epochs.append(i)
```


```
In [17]: plt.plot(epochs, accr, label="Test Data")
plt.plot(epochs, accr_train, label="Train Data")
plt.legend(bbox_to_anchor=(1.05, 1), loc=2, borderaxespad=0.)
plt.xlabel('epochs')
plt.ylabel('accuracy')
plt.show()
```



```
In [18]: acc()
```

```
Out[18]: 0.93611109
```

In [19]: `show_graph(tf.get_default_graph())` *#not that great, we should probably use scopes*

 Fit to screen










Run

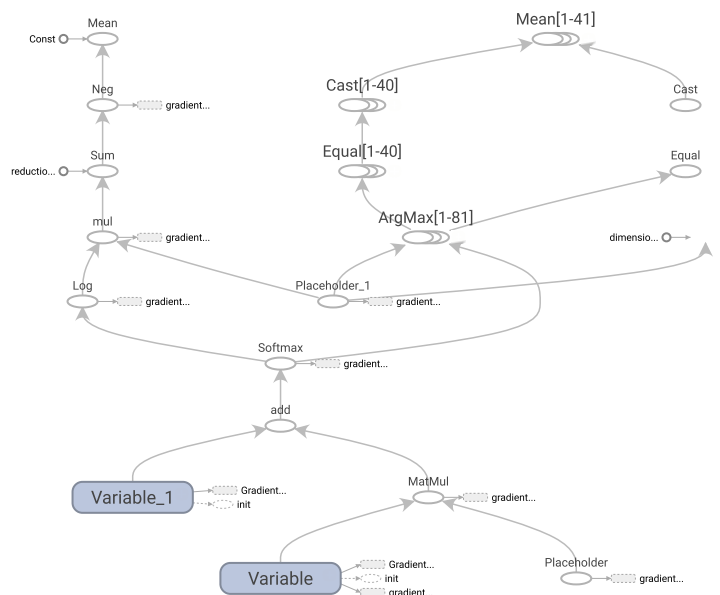
Upload

Choose File

Color
 Structure
 color: same substructure
 gray: unique substructure

Graph (* = expandable)

-  Namespace*
-  OpNode
-  Unconnected series*
-  Connected series*
-  Constant
-  Summary
-  Dataflow edge
-  Control dependency edge
-  Reference edge



In [20]: `# PART 2B DNN`

In [21]: `# Define hyperparameters and input size`

```
n_inputs = 8*8 # DIGITS
n_hidden1 = 300
n_hidden2 = 200
n_hidden3 = 100
n_outputs = 10
```

In [22]: `# Reset graph`
`tf.reset_default_graph()`

```
In [23]: # Placeholders for data (inputs and targets)
X = tf.placeholder(tf.float32, shape=(None, n_inputs), name="X")
y = tf.placeholder(tf.int64, shape=(None), name="y")
```

```
In [24]: # Define neuron layers (ReLU in hidden layers)
# We'll take care of Softmax for output with Loss function

def neuron_layer(X, n_neurons, name, activation=None):
    # X input to neuron
    # number of neurons for the layer
    # name of layer
    # pass in eventual activation function

    with tf.name_scope(name):
        n_inputs = int(X.get_shape()[1])

        # initialize weights to prevent vanishing / exploding gradients
        stddev = 2 / np.sqrt(n_inputs)
        init = tf.truncated_normal((n_inputs, n_neurons), stddev=stddev)

        # Initialize weights for the layer
        W = tf.Variable(init, name="weights")
        # biases
        b = tf.Variable(tf.zeros([n_neurons]), name="bias")

        # Output from every neuron
        Z = tf.matmul(X, W) + b
        if activation is not None:
            return activation(Z)
        else:
            return Z
```

```
In [25]: # Define the hidden layers
keep_prob = 0.9
with tf.name_scope("dnn"):
    hidden1 = neuron_layer(X, n_hidden1, name="hidden1",
                           activation=tf.nn.tanh)
    drop_out1 = tf.nn.dropout(hidden1, keep_prob)

    hidden2 = neuron_layer(drop_out1, n_hidden2, name="hidden2",
                           activation=tf.nn.tanh)
    drop_out2 = tf.nn.dropout(hidden2, keep_prob)

    hidden3 = neuron_layer(drop_out2, n_hidden3, name="hidden3",
                           activation=tf.nn.tanh)
    drop_out3 = tf.nn.dropout(hidden3, keep_prob)

    logits = neuron_layer(drop_out3, n_outputs, name="outputs")
```

```
In [26]: # Define loss function (that also optimizes Softmax for output):

with tf.name_scope("loss"):
    # logits are from the last output of the dnn
    xentropy = tf.nn.sparse_softmax_cross_entropy_with_logits(labels=y,
                                                              logits=logits)
    loss = tf.reduce_mean(xentropy, name="loss")
```

```
In [27]: # Training step with Gradient Descent

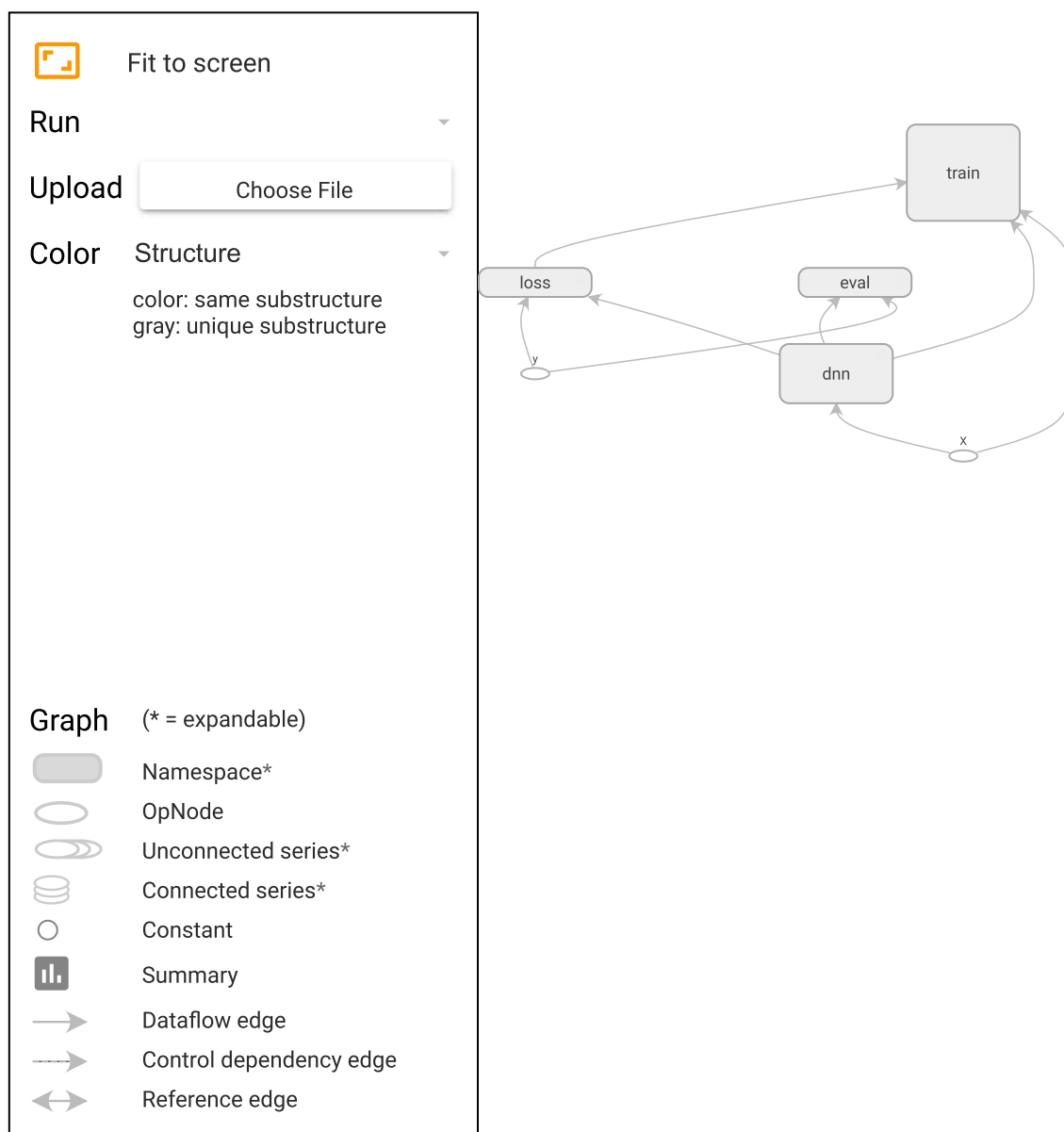
learning_rate = 0.001

with tf.name_scope("train"):
    optimizer = tf.train.GradientDescentOptimizer(learning_rate)
    training_op = optimizer.minimize(loss)
```

```
In [28]: # Evaluation to see accuracy

with tf.name_scope("eval"):
    correct = tf.nn.in_top_k(logits, y, 1)
    accuracy = tf.reduce_mean(tf.cast(correct, tf.float32))
```


In [29]: `show_graph(tf.get_default_graph())`



```
In [30]: init = tf.global_variables_initializer()
saver = tf.train.Saver()

n_epochs = 1000
batch_size = 100

epoch_arr = []
acc_tr_arr = []
acc_v_arr = []

with tf.Session() as sess:
    init.run()
    for epoch in range(n_epochs):
        #         for iteration in range(mnist.train.num_examples // batch_size):
        #             X_batch, y_batch = mnist.train.next_batch(batch_size)
        #             sess.run(training_op, feed_dict={X: X_batch, y: y_batch})
        for i in range(len(x_train)//batch_size):
            batch_xs, batch_ys = next_batch(batch_size, X_train, y_train2)
            #             print(batch_xs)
            sess.run(training_op, feed_dict={X: batch_xs, y: batch_ys})

        acc_train = accuracy.eval(feed_dict={X: batch_xs, y: batch_ys})
        acc_val = accuracy.eval(feed_dict={X: X_test,
                                           y: y_test2})
        print(epoch, "Train accuracy:", acc_train, "Val accuracy:", acc_val)
        epoch_arr.append(epoch)
        acc_tr_arr.append(acc_train)
        acc_v_arr.append(acc_val)

save_path = saver.save(sess, "./my_model_final.ckpt") # save model
```

0 Train accuracy: 0.15 Val accuracy: 0.0944444
1 Train accuracy: 0.06 Val accuracy: 0.116667
2 Train accuracy: 0.07 Val accuracy: 0.125
3 Train accuracy: 0.17 Val accuracy: 0.122222
4 Train accuracy: 0.15 Val accuracy: 0.163889
5 Train accuracy: 0.16 Val accuracy: 0.147222
6 Train accuracy: 0.2 Val accuracy: 0.188889
7 Train accuracy: 0.25 Val accuracy: 0.211111
8 Train accuracy: 0.22 Val accuracy: 0.222222
9 Train accuracy: 0.28 Val accuracy: 0.241667
10 Train accuracy: 0.31 Val accuracy: 0.258333
11 Train accuracy: 0.3 Val accuracy: 0.269444
12 Train accuracy: 0.38 Val accuracy: 0.297222
13 Train accuracy: 0.33 Val accuracy: 0.308333
14 Train accuracy: 0.37 Val accuracy: 0.369444
15 Train accuracy: 0.4 Val accuracy: 0.344444
16 Train accuracy: 0.48 Val accuracy: 0.383333
17 Train accuracy: 0.36 Val accuracy: 0.363889
18 Train accuracy: 0.43 Val accuracy: 0.391667
19 Train accuracy: 0.39 Val accuracy: 0.380556
20 Train accuracy: 0.63 Val accuracy: 0.433333
21 Train accuracy: 0.47 Val accuracy: 0.436111
22 Train accuracy: 0.47 Val accuracy: 0.466667
23 Train accuracy: 0.5 Val accuracy: 0.441667
24 Train accuracy: 0.52 Val accuracy: 0.480556
25 Train accuracy: 0.51 Val accuracy: 0.477778
26 Train accuracy: 0.65 Val accuracy: 0.511111
27 Train accuracy: 0.65 Val accuracy: 0.475
28 Train accuracy: 0.56 Val accuracy: 0.530556
29 Train accuracy: 0.62 Val accuracy: 0.563889
30 Train accuracy: 0.63 Val accuracy: 0.541667
31 Train accuracy: 0.59 Val accuracy: 0.547222
32 Train accuracy: 0.53 Val accuracy: 0.6
33 Train accuracy: 0.68 Val accuracy: 0.577778
34 Train accuracy: 0.66 Val accuracy: 0.616667
35 Train accuracy: 0.68 Val accuracy: 0.597222
36 Train accuracy: 0.59 Val accuracy: 0.547222
37 Train accuracy: 0.68 Val accuracy: 0.6
38 Train accuracy: 0.62 Val accuracy: 0.627778
39 Train accuracy: 0.62 Val accuracy: 0.638889
40 Train accuracy: 0.63 Val accuracy: 0.652778
41 Train accuracy: 0.72 Val accuracy: 0.608333
42 Train accuracy: 0.76 Val accuracy: 0.627778
43 Train accuracy: 0.72 Val accuracy: 0.641667
44 Train accuracy: 0.64 Val accuracy: 0.65
45 Train accuracy: 0.6 Val accuracy: 0.625
46 Train accuracy: 0.71 Val accuracy: 0.666667
47 Train accuracy: 0.69 Val accuracy: 0.663889
48 Train accuracy: 0.7 Val accuracy: 0.686111
49 Train accuracy: 0.75 Val accuracy: 0.661111
50 Train accuracy: 0.85 Val accuracy: 0.661111
51 Train accuracy: 0.73 Val accuracy: 0.611111
52 Train accuracy: 0.75 Val accuracy: 0.683333
53 Train accuracy: 0.72 Val accuracy: 0.677778
54 Train accuracy: 0.71 Val accuracy: 0.680556
55 Train accuracy: 0.78 Val accuracy: 0.702778
56 Train accuracy: 0.78 Val accuracy: 0.702778

57 Train accuracy: 0.75 Val accuracy: 0.694444
58 Train accuracy: 0.75 Val accuracy: 0.708333
59 Train accuracy: 0.76 Val accuracy: 0.711111
60 Train accuracy: 0.71 Val accuracy: 0.711111
61 Train accuracy: 0.69 Val accuracy: 0.716667
62 Train accuracy: 0.73 Val accuracy: 0.702778
63 Train accuracy: 0.69 Val accuracy: 0.697222
64 Train accuracy: 0.8 Val accuracy: 0.702778
65 Train accuracy: 0.79 Val accuracy: 0.722222
66 Train accuracy: 0.8 Val accuracy: 0.738889
67 Train accuracy: 0.83 Val accuracy: 0.747222
68 Train accuracy: 0.82 Val accuracy: 0.744444
69 Train accuracy: 0.77 Val accuracy: 0.733333
70 Train accuracy: 0.84 Val accuracy: 0.747222
71 Train accuracy: 0.78 Val accuracy: 0.763889
72 Train accuracy: 0.88 Val accuracy: 0.763889
73 Train accuracy: 0.78 Val accuracy: 0.741667
74 Train accuracy: 0.84 Val accuracy: 0.744444
75 Train accuracy: 0.81 Val accuracy: 0.766667
76 Train accuracy: 0.88 Val accuracy: 0.772222
77 Train accuracy: 0.83 Val accuracy: 0.786111
78 Train accuracy: 0.79 Val accuracy: 0.766667
79 Train accuracy: 0.78 Val accuracy: 0.758333
80 Train accuracy: 0.82 Val accuracy: 0.775
81 Train accuracy: 0.86 Val accuracy: 0.791667
82 Train accuracy: 0.88 Val accuracy: 0.761111
83 Train accuracy: 0.86 Val accuracy: 0.758333
84 Train accuracy: 0.79 Val accuracy: 0.763889
85 Train accuracy: 0.84 Val accuracy: 0.772222
86 Train accuracy: 0.85 Val accuracy: 0.763889
87 Train accuracy: 0.85 Val accuracy: 0.797222
88 Train accuracy: 0.87 Val accuracy: 0.786111
89 Train accuracy: 0.88 Val accuracy: 0.783333
90 Train accuracy: 0.89 Val accuracy: 0.811111
91 Train accuracy: 0.84 Val accuracy: 0.777778
92 Train accuracy: 0.88 Val accuracy: 0.797222
93 Train accuracy: 0.85 Val accuracy: 0.783333
94 Train accuracy: 0.81 Val accuracy: 0.791667
95 Train accuracy: 0.85 Val accuracy: 0.786111
96 Train accuracy: 0.84 Val accuracy: 0.783333
97 Train accuracy: 0.79 Val accuracy: 0.777778
98 Train accuracy: 0.92 Val accuracy: 0.805556
99 Train accuracy: 0.83 Val accuracy: 0.769444
100 Train accuracy: 0.86 Val accuracy: 0.797222
101 Train accuracy: 0.84 Val accuracy: 0.791667
102 Train accuracy: 0.93 Val accuracy: 0.816667
103 Train accuracy: 0.83 Val accuracy: 0.8
104 Train accuracy: 0.88 Val accuracy: 0.836111
105 Train accuracy: 0.88 Val accuracy: 0.783333
106 Train accuracy: 0.85 Val accuracy: 0.811111
107 Train accuracy: 0.91 Val accuracy: 0.805556
108 Train accuracy: 0.83 Val accuracy: 0.791667
109 Train accuracy: 0.88 Val accuracy: 0.813889
110 Train accuracy: 0.87 Val accuracy: 0.813889
111 Train accuracy: 0.88 Val accuracy: 0.811111
112 Train accuracy: 0.93 Val accuracy: 0.794444
113 Train accuracy: 0.91 Val accuracy: 0.836111

114 Train accuracy: 0.92 Val accuracy: 0.827778
115 Train accuracy: 0.89 Val accuracy: 0.805556
116 Train accuracy: 0.84 Val accuracy: 0.808333
117 Train accuracy: 0.87 Val accuracy: 0.813889
118 Train accuracy: 0.88 Val accuracy: 0.833333
119 Train accuracy: 0.92 Val accuracy: 0.830556
120 Train accuracy: 0.83 Val accuracy: 0.841667
121 Train accuracy: 0.85 Val accuracy: 0.841667
122 Train accuracy: 0.91 Val accuracy: 0.836111
123 Train accuracy: 0.88 Val accuracy: 0.816667
124 Train accuracy: 0.87 Val accuracy: 0.819444
125 Train accuracy: 0.89 Val accuracy: 0.855556
126 Train accuracy: 0.85 Val accuracy: 0.833333
127 Train accuracy: 0.84 Val accuracy: 0.830556
128 Train accuracy: 0.84 Val accuracy: 0.819444
129 Train accuracy: 0.88 Val accuracy: 0.819444
130 Train accuracy: 0.92 Val accuracy: 0.841667
131 Train accuracy: 0.81 Val accuracy: 0.825
132 Train accuracy: 0.83 Val accuracy: 0.847222
133 Train accuracy: 0.85 Val accuracy: 0.825
134 Train accuracy: 0.87 Val accuracy: 0.819444
135 Train accuracy: 0.86 Val accuracy: 0.836111
136 Train accuracy: 0.88 Val accuracy: 0.827778
137 Train accuracy: 0.89 Val accuracy: 0.833333
138 Train accuracy: 0.88 Val accuracy: 0.822222
139 Train accuracy: 0.88 Val accuracy: 0.833333
140 Train accuracy: 0.85 Val accuracy: 0.833333
141 Train accuracy: 0.87 Val accuracy: 0.855556
142 Train accuracy: 0.88 Val accuracy: 0.838889
143 Train accuracy: 0.88 Val accuracy: 0.836111
144 Train accuracy: 0.92 Val accuracy: 0.836111
145 Train accuracy: 0.92 Val accuracy: 0.869444
146 Train accuracy: 0.92 Val accuracy: 0.847222
147 Train accuracy: 0.9 Val accuracy: 0.855556
148 Train accuracy: 0.85 Val accuracy: 0.858333
149 Train accuracy: 0.87 Val accuracy: 0.858333
150 Train accuracy: 0.87 Val accuracy: 0.811111
151 Train accuracy: 0.89 Val accuracy: 0.861111
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159 Train accuracy: 0.9 Val accuracy: 0.852778
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164 Train accuracy: 0.93 Val accuracy: 0.858333
165 Train accuracy: 0.95 Val accuracy: 0.841667
166 Train accuracy: 0.91 Val accuracy: 0.841667
167 Train accuracy: 0.88 Val accuracy: 0.872222
168 Train accuracy: 0.85 Val accuracy: 0.894444
169 Train accuracy: 0.9 Val accuracy: 0.844444
170 Train accuracy: 0.91 Val accuracy: 0.869444

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185 Train accuracy: 0.92 Val accuracy: 0.852778
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226 Train accuracy: 0.95 Val accuracy: 0.883333
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256 Train accuracy: 0.97 Val accuracy: 0.880556
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In [31]: plt.plot(epoch_arr, acc_tr_arr, label="Train Data")
plt.plot(epoch_arr, acc_v_arr, label="Validate Data")
plt.legend(bbox_to_anchor=(1.05, 1), loc=2, borderaxespad=0.)
plt.xlabel('epochs')
plt.ylabel('accuracy')
plt.show()
```

