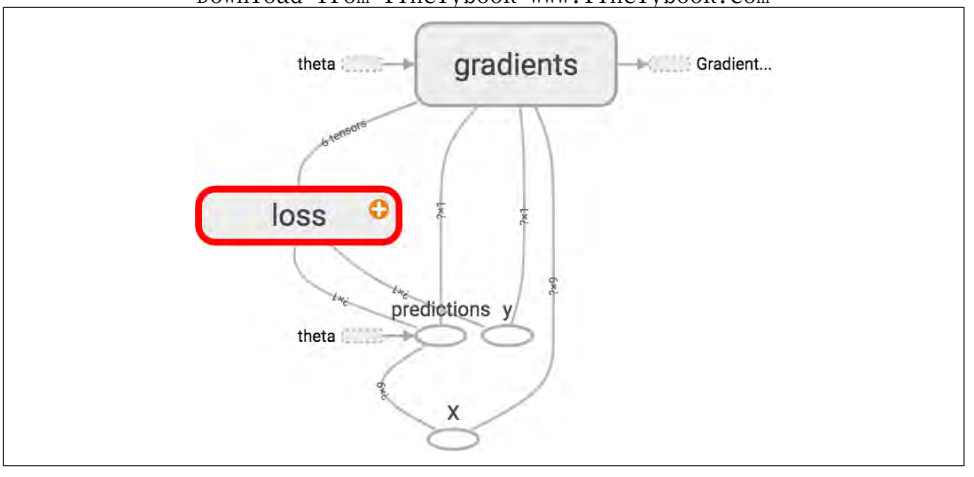

Figure 9-5. A collapsed namescope in TensorBoard

Modularity

Suppose you want to create a graph that adds the output of two *rectified linear units* (ReLU). A ReLU computes a linear function of the inputs, and outputs the result if it is positive, and 0 otherwise, as shown in Equation 9-1.

Equation 9-1. Rectified linear unit

$$h_{\mathbf{w},b}(\mathbf{X}) = \max(\mathbf{X} \cdot \mathbf{w} + b, 0)$$

The following code does the job, but it's quite repetitive:

```
n_features = 3
X = tf.placeholder(tf.float32, shape=(None, n_features), name="X")

w1 = tf.Variable(tf.random_normal((n_features, 1)), name="weights1")
w2 = tf.Variable(tf.random_normal((n_features, 1)), name="weights2")
b1 = tf.Variable(0.0, name="bias1")
b2 = tf.Variable(0.0, name="bias2")

z1 = tf.add(tf.matmul(X, w1), b1, name="z1")
z2 = tf.add(tf.matmul(X, w2), b2, name="z2")

relu1 = tf.maximum(z1, 0., name="relu1")
relu2 = tf.maximum(z1, 0., name="relu2")

output = tf.add(relu1, relu2, name="output")
```

Such repetitive code is hard to maintain and error-prone (in fact, this code contains a cut-and-paste error; did you spot it?). It would become even worse if you wanted to

add a few more ReLUs. Fortunately, TensorFlow lets you stay DRY (Don't Repeat Yourself): simply create a function to build a ReLU. The following code creates five ReLUs and outputs their sum (note that `add_n()` creates an operation that will compute the sum of a list of tensors):

```
def relu(X):
    w_shape = (int(X.get_shape()[1]), 1)
    w = tf.Variable(tf.random_normal(w_shape), name="weights")
    b = tf.Variable(0.0, name="bias")
    z = tf.add(tf.matmul(X, w), b, name="z")
    return tf.maximum(z, 0., name="relu")

n_features = 3
X = tf.placeholder(tf.float32, shape=(None, n_features), name="X")
relus = [relu(X) for i in range(5)]
output = tf.add_n(relus, name="output")
```

Note that when you create a node, TensorFlow checks whether its name already exists, and if it does it appends an underscore followed by an index to make the name unique. So the first ReLU contains nodes named `"weights"`, `"bias"`, `"z"`, and `"relu"` (plus many more nodes with their default name, such as `"MatMul"`); the second ReLU contains nodes named `"weights_1"`, `"bias_1"`, and so on; the third ReLU contains nodes named `"weights_2"`, `"bias_2"`, and so on. TensorBoard identifies such series and collapses them together to reduce clutter (as you can see in Figure 9-6).

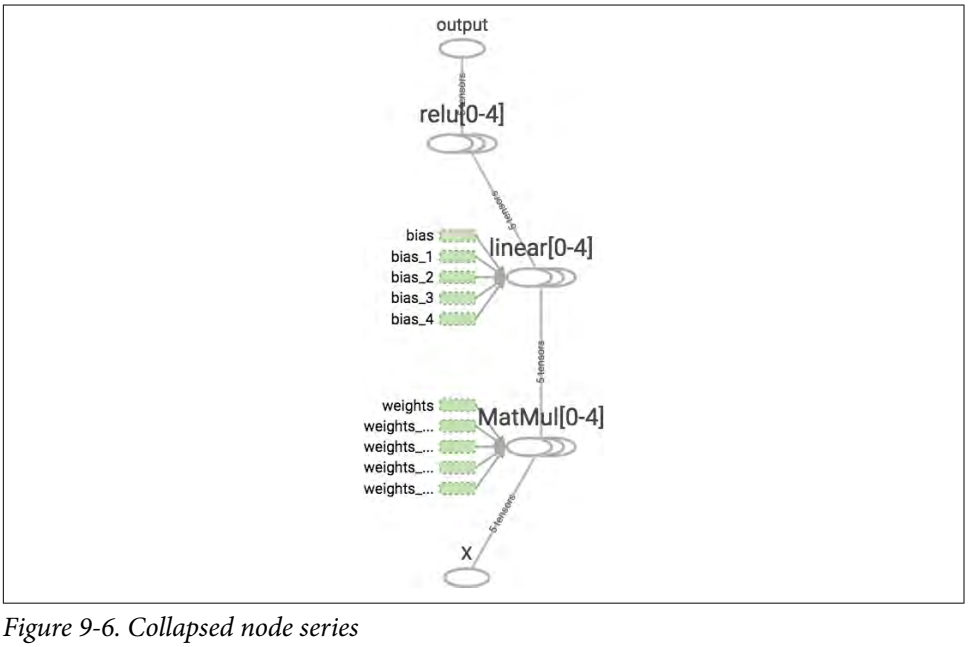

Figure 9-6. Collapsed node series

Using name scopes, you can make the graph much clearer. Simply move all the content of the `relu()` function inside a name scope. Figure 9-7 shows the resulting graph. Notice that TensorFlow also gives the name scopes unique names by appending `_1`, `_2`, and so on.

```
def relu(X):
    with tf.name_scope("relu"):
        [...]
```

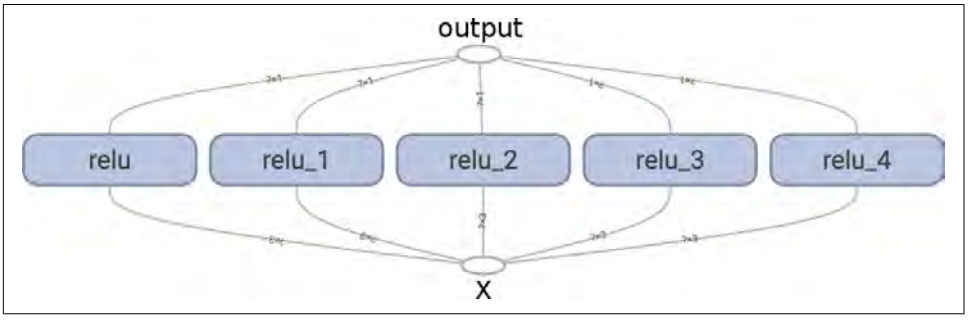

Figure 9-7. A clearer graph using name-scoped units

Sharing Variables

If you want to share a variable between various components of your graph, one simple option is to create it first, then pass it as a parameter to the functions that need it. For example, suppose you want to control the ReLU threshold (currently hardcoded to 0) using a shared `threshold` variable for all ReLUs. You could just create that variable first, and then pass it to the `relu()` function:

```
def relu(X, threshold):
    with tf.name_scope("relu"):
        [...]
        return tf.maximum(z, threshold, name="max")

threshold = tf.Variable(0.0, name="threshold")
X = tf.placeholder(tf.float32, shape=(None, n_features), name="X")
relus = [relu(X, threshold) for i in range(5)]
output = tf.add_n(relus, name="output")
```

This works fine: now you can control the threshold for all ReLUs using the `threshold` variable. However, if there are many shared parameters such as this one, it will be painful to have to pass them around as parameters all the time. Many people create a Python dictionary containing all the variables in their model, and pass it around to every function. Others create a class for each module (e.g., a `ReLU` class using class variables to handle the shared parameter). Yet another option is to set the shared variable as an attribute of the `relu()` function upon the first call, like so: