Mandelbrot Set

Visualizing the Mandelbrot set doesn't have anything to do with machine learning, but it makes for a fun example of how one can use TensorFlow for general mathematics. This is actually a pretty naive implementation of the visualization, but it makes the point. (We may end up providing a more elaborate implementation down the line to produce more truly beautiful images.)

Note: This tutorial was originally prepared as an IPython notebook.

Basic Setup

We'll need a few imports to get started.

```
# Import libraries for simulation
import tensorflow as tf
import numpy as np

# Imports for visualization
import PIL.Image
from cStringIO import StringIO
from IPython.display import clear_output, Image, display
import scipy.ndimage as nd
```

Now we'll define a function to actually display the image once we have iteration counts.

```
def DisplayFractal(a, fmt='jpeg'):
  """Display an array of iteration counts as a
     colorful picture of a fractal."""
  a_cyclic = (6.28*a/20.0).reshape(list(a.shape)+[1])
  img = np.concatenate([10+20*np.cos(a_cyclic),
                        30+50*np.sin(a_cyclic),
                        155-80*np.cos(a_cyclic)], 2)
  img[a==a.max()] = 0
```

```
a = img
a = np.uint8(np.clip(a, 0, 255))
f = StringIO()
PIL.Image.fromarray(a).save(f, fmt)
display(Image(data=f.getvalue()))
```

Session and Variable Initialization

For playing around like this, we often use an interactive session, but a regular session would work as well.

```
sess = tf.InteractiveSession()
```

It's handy that we can freely mix NumPy and TensorFlow.

```
# Use NumPy to create a 2D array of complex numbers on [-2,2]x[-2,2]

Y, X = np.mgrid[-1.3:1.3:0.005, -2:1:0.005]
Z = X+1j*Y
```

Now we define and initialize TensorFlow tensors.

```
xs = tf.constant(Z.astype("complex64"))
zs = tf.Variable(xs)
ns = tf.Variable(tf.zeros_like(xs, "float32"))
```

TensorFlow requires that you explicitly initialize variables before using them.

```
tf.initialize_all_variables().run()
```

Defining and Running the Computation

Now we specify more of the computation...

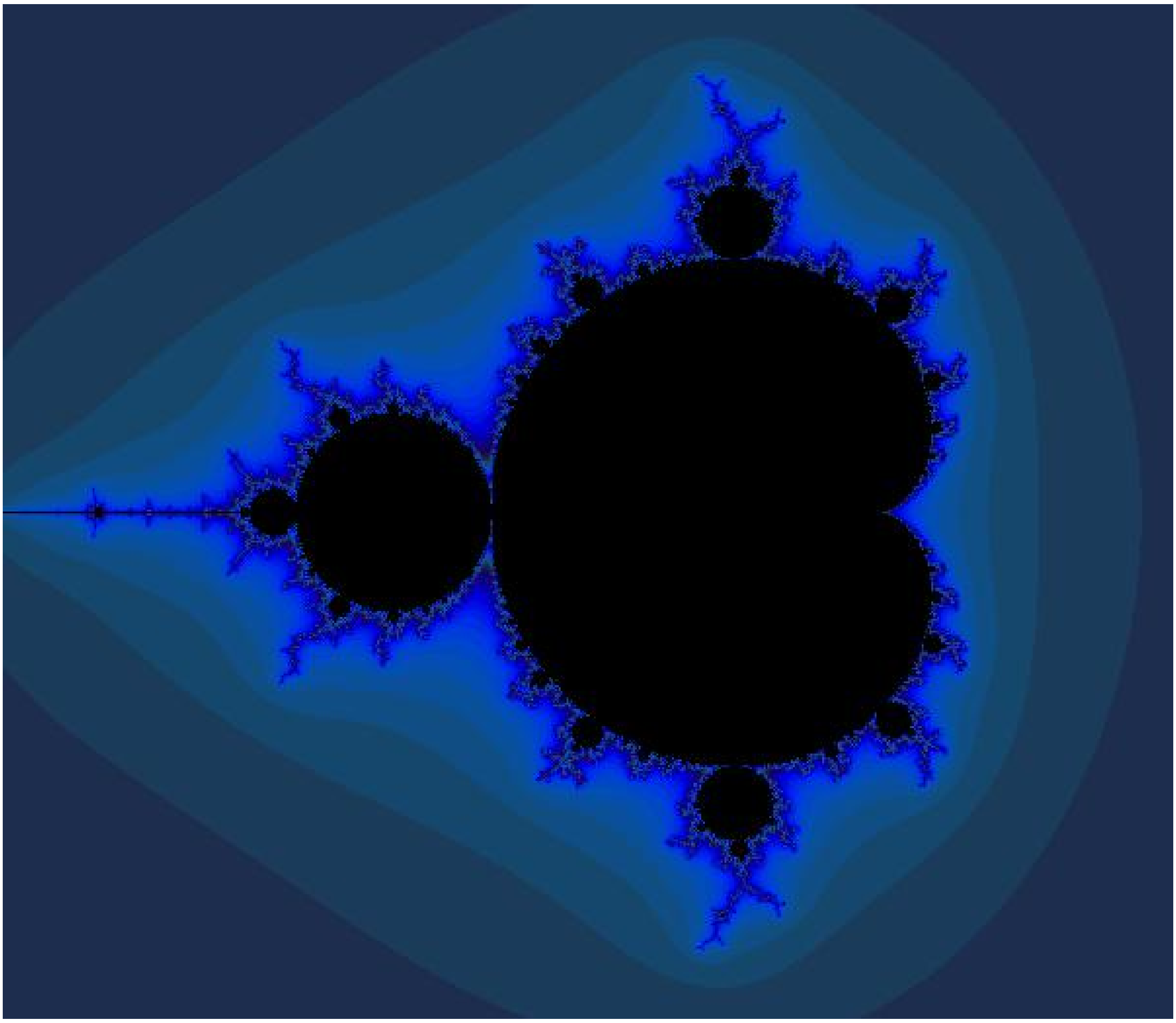
```
# Compute the new values of z: z^2 + x
zs_ = zs*zs + xs

# Have we diverged with this new value?
not_diverged = tf.complex_abs(zs_) < 4

# Operation to update the zs and the iteration count.
#
# Note: We keep computing zs after they diverge! This
#       is very wasteful! There are better, if a little
#       less simple, ways to do this.
#
step = tf.group(
  zs.assign(zs_),
  ns.assign_add(tf.cast(not_diverged, "float32"))
  )
```

... and run it for a couple hundred steps

```
for i in range(200): step.run()
```

Let's see what we've got.

```
DisplayFractal(ns.eval())
```



Not bad!