Adversarial-Examples

June 10, 2018

```
In [1]: import numpy as np
        import matplotlib.pyplot as plt
        import pandas as pd
        import random
        import tensorflow as tf
        from tensorflow.contrib.tensor_forest.python import tensor_forest
        from tensorflow.python.ops import resources
        from tensorflow.examples.tutorials.mnist import input_data

In [2]: np.random.seed(1)
```

0.1 1. Obtain the MNIST dataset and normalize it for use with a classifier.

```
In [4]: # The mnist dataset is already normalized
        mnist = input_data.read_data_sets("./data/", one_hot=True)
```

```
Extracting ./data/train-images-idx3-ubyte.gz
Extracting ./data/train-labels-idx1-ubyte.gz
Extracting ./data/t10k-images-idx3-ubyte.gz
Extracting ./data/t10k-labels-idx1-ubyte.gz
```

0.2 2. Select two different machine learning classification models

0.2.1 A: Logistic regression

```
In [5]: #https://github.com/aymericdamien/TensorFlow-Examples/blob/master/notebooks/2_BasicModel

        class LogisticRegression():
            def __init__(self, input_size, output_size, learning_rate=0.01,
                         training_epochs= 100, batch_size=100, display_step=1):
                self.learning_rate = learning_rate
                self.training_epochs = training_epochs
                self.batch_size = batch_size
                self.display_step = display_step

                self.x = tf.placeholder(tf.float32, [None, input_size]) # mnist data image of sh
                self.y = tf.placeholder(tf.float32, [None, output_size]) # 0-9 digits recognitio
```

```
        # Set model weights
        self.W = tf.Variable(tf.zeros([input_size, output_size]))
        self.b = tf.Variable(tf.zeros([output_size]))

        # Construct model
        self.pred = tf.nn.softmax(tf.matmul(self.x, self.W) + self.b)
        self.correct_pred = tf.equal(tf.argmax(self.pred, 1), tf.argmax(self.y, 1))
        self.accuracy = tf.reduce_mean(tf.cast(self.correct_pred, tf.float32))

        # Minimize error using cross entropy
        self.loss = tf.reduce_mean(-tf.reduce_sum(self.y*tf.log(self.pred), reduction_in

        # Gradient Descent
        self.optimizer = tf.train.GradientDescentOptimizer(self.learning_rate).minimize(

        # Calculate loss with respect to input
        self.gradient_input = tf.gradients(self.loss, self.x)[0]

        # Initialize the variables (i.e. assign their default value)
        self.init = tf.global_variables_initializer()

    def fit(self, images, labels, sess = None):
        sessionCreated = False

        if sess is None:
            sess = tf.Session()
            sess.run(self.init)

            sessionCreated = True

        # Training cycle
        for epoch in range(self.training_epochs):
            avg_loss = 0.
            total_batch = int(len(images)/self.batch_size)

            # Loop over all batches
            for i in range(total_batch):
                batch_xs = images[i*self.batch_size: (i+1)*self.batch_size]
                batch_ys = labels[i*self.batch_size: (i+1)*self.batch_size]

                # Run optimization op (backprop) and loss op (to get loss value)
                _, acc, c = sess.run([self.optimizer, self.accuracy, self.loss], feed_di
                                                                self.y: batch_ys})
                # Compute average loss
                avg_loss += c / total_batch

            # Display logs per epoch step
```

```
            if self.display_step > 0 and (epoch+1) % self.display_step == 0:
                print "Epoch: {}, loss: {:.4f}, acc:{:.4f}".format(epoch+1, avg_loss, ac

        if sessionCreated:
            sess.close()

    def measure_accuracy(self, images, labels, sess=None):
        sessionCreated = False

        if sess is None:
            sess = tf.Session()
            sess.run(self.init)

            sessionCreated = True

        print "Test accuracy:", sess.run(self.accuracy,
                                         feed_dict = {self.x:images, self.y:labels})


        if sessionCreated:
            sess.close()

    def get_adversarial_images(self, images, labels, sess=None):
        sessionCreated = False

        if sess is None:
            sess = tf.Session()
            sess.run(self.init)

            sessionCreated = True

        pred_y = []
        adv_x = []
        adv_y = []
        for index, [image, label] in enumerate(zip(images, labels)):
            pred, grad = sess.run([self.pred, self.gradient_input], feed_dict = {
                self.x:np.expand_dims(image, 0), self.y:np.expand_dims(label, 0)})

            adversarial_img_op = image + 0.2 * tf.sign(grad)
            adversarial_img = adversarial_img_op.eval(session=sess)

            ad_pred = sess.run(self.pred, feed_dict = {
                self.x:adversarial_img, self.y:np.expand_dims(label, 0)})

            pred_y.append(pred[0])
            adv_x.append(adversarial_img[0])
            adv_y.append(ad_pred[0])
```

```
            if sessionCreated:
                sess.close()

            return pred_y, adv_x, adv_y
```

0.2.2 B: Convolutional Neural Network

```
In [8]: # REF: https://github.com/aymericdamien/TensorFlow-Examples/blob/master/notebooks/3_Neur
        class CNN():
            def __init__(self, input_size, output_size, learning_rate=0.001,
                         training_epochs= 1, batch_size=200, dropout=0.75, display_step=10):
                self.learning_rate = learning_rate
                self.training_epochs = training_epochs
                self.batch_size = batch_size
                self.display_step = display_step
                self.dropout = dropout

                self.x = tf.placeholder(tf.float32, [None, input_size])
                self.y = tf.placeholder(tf.float32, [None, output_size])
                self.keep_prob = tf.placeholder(tf.float32) # dropout (keep probability)

                # Create some wrappers for simplicity
                def conv2d(x, W, b, strides=1):
                    # Conv2D wrapper, with bias and relu activation
                    x = tf.nn.conv2d(x, W, strides=[1, strides, strides, 1], padding='SAME')
                    x = tf.nn.bias_add(x, b)
                    return tf.nn.relu(x)


                def maxpool2d(x, k=2):
                    # MaxPool2D wrapper
                    return tf.nn.max_pool(x, ksize=[1, k, k, 1], strides=[1, k, k, 1],
                                          padding='SAME')


                # Create model
                def conv_net(x, weights, biases, dropout):
                    # MNIST data input is a 1-D vector of 784 features (28*28 pixels)
                    # Reshape to match picture format [Height x Width x Channel]
                    # Tensor input become 4-D: [Batch Size, Height, Width, Channel]
                    x = tf.reshape(x, shape=[-1, 28, 28, 1])

                    # Convolution Layer
                    conv1 = conv2d(x, weights['wc1'], biases['bc1'])
                    # Max Pooling (down-sampling)
                    conv1 = maxpool2d(conv1, k=2)

                    # Convolution Layer
```

```
        conv2 = conv2d(conv1, weights['wc2'], biases['bc2'])
        # Max Pooling (down-sampling)
        conv2 = maxpool2d(conv2, k=2)

        # Fully connected layer
        # Reshape conv2 output to fit fully connected layer input
        fc1 = tf.reshape(conv2, [-1, weights['wd1'].get_shape().as_list()[0]])
        fc1 = tf.add(tf.matmul(fc1, weights['wd1']), biases['bd1'])
        fc1 = tf.nn.relu(fc1)
        # Apply Dropout
        fc1 = tf.nn.dropout(fc1, dropout)

        # Output, class prediction
        out = tf.add(tf.matmul(fc1, weights['out']), biases['out'])
        return out

    # Store layers weight & bias
    self.weights = {
        # 5x5 conv, 1 input, 32 outputs
        'wc1': tf.Variable(tf.random_normal([5, 5, 1, 32])),
        # 5x5 conv, 32 inputs, 64 outputs
        'wc2': tf.Variable(tf.random_normal([5, 5, 32, 64])),
        # fully connected, 7*7*64 inputs, 1024 outputs
        'wd1': tf.Variable(tf.random_normal([7*7*64, 1024])),
        # 1024 inputs, 10 outputs (class prediction)
        'out': tf.Variable(tf.random_normal([1024, output_size]))
    }

    self.biases = {
        'bc1': tf.Variable(tf.random_normal([32])),
        'bc2': tf.Variable(tf.random_normal([64])),
        'bd1': tf.Variable(tf.random_normal([1024])),
        'out': tf.Variable(tf.random_normal([output_size]))
    }

    # Construct model
    self.logits = conv_net(self.x, self.weights, self.biases, self.keep_prob)
    self.prediction = tf.nn.softmax(self.logits)

    # Define loss and optimizer
    self.loss_op = tf.reduce_mean(tf.nn.softmax_cross_entropy_with_logits(
        logits=self.logits, labels=self.y))

    # Calculate loss with respect to input
    self.gradient_input = tf.gradients(self.loss_op, self.x)[0]

    self.optimizer = tf.train.AdamOptimizer(learning_rate=self.learning_rate)
    self.train_op = self.optimizer.minimize(self.loss_op)
```

```
        # Evaluate model
        self.correct_pred = tf.equal(tf.argmax(self.prediction, 1), tf.argmax(self.y, 1)
        self.accuracy = tf.reduce_mean(tf.cast(self.correct_pred, tf.float32))

        # Initialize the variables (i.e. assign their default value)
        self.init = tf.global_variables_initializer()


    def fit(self, images, labels, sess = None):
        sessionCreated = False

        if sess is None:
            sess = tf.Session()
            sess.run(self.init)

            sessionCreated = True

        # Training cycle
        for step in range(1, self.training_epochs+1):
            total_batch = int(len(images)/self.batch_size)

            # Loop over all batches
            for i in range(total_batch):
                batch_x = images[i*self.batch_size: (i+1)*self.batch_size]
                batch_y = labels[i*self.batch_size: (i+1)*self.batch_size]

                # Run optimization op (backprop)
                sess.run(self.train_op, feed_dict={self.x: batch_x, self.y: batch_y, sel

                count = step*i
                if self.display_step>0 and (count % self.display_step == 0 or count == 1
                    # Calculate batch loss and accuracy
                    loss, acc = sess.run([self.loss_op, self.accuracy], feed_dict={self.
                                                                         self.y: batch_y
                                                                         self.keep_prob:
                    print "Epoch: {}, loss: {:.4f}, acc:{:.4f}".format(count, loss, acc)

        if sessionCreated:
            sess.close()

    def measure_accuracy(self, images, labels, sess=None):
        sessionCreated = False

        if sess is None:
            sess = tf.Session()
            sess.run(self.init)
```

```
            sessionCreated = True

        print "Test accuracy:", sess.run(self.accuracy,
                  feed_dict = {self.x:images[0:256],
                               self.y:labels[0:256], self.keep_prob: 1.0})


        if sessionCreated:
            sess.close()

    def get_adversarial_images(self, images, labels, sess=None):
        sessionCreated = False

        if sess is None:
            sess = tf.Session()
            sess.run(self.init)

            sessionCreated = True

        pred_y = []
        adv_x = []
        adv_y = []
        for index, [image, label] in enumerate(zip(images, labels)):
            pred, grad = sess.run([self.prediction, self.gradient_input], feed_dict = {
                self.x:np.expand_dims(image, 0), self.y:np.expand_dims(label, 0), self.k

            adversarial_img_op = image + 0.2 * tf.sign(grad)
            adversarial_img = adversarial_img_op.eval(session=sess)

            ad_pred = sess.run(self.prediction, feed_dict = {
                self.x:adversarial_img, self.y:np.expand_dims(label, 0), self.keep_prob:

            pred_y.append(pred[0])
            adv_x.append(adversarial_img[0])
            adv_y.append(ad_pred[0])

        if sessionCreated:
            sess.close()

        return pred_y, adv_x, adv_y
```

C: Random forest (Did not use this for adversarial example because tf.gradients(...) throws error for tensor_forest)

```
In [9]: # https://github.com/aymericdamien/TensorFlow-Examples/blob/master/examples/2_BasicModel

        class RandomForest():
```

```python
def __init__(self, input_size, output_size, training_epochs= 500,
             batch_size=1024, num_trees=10, max_nodes = 1000, display_step=1):
    self.training_epochs = training_epochs
    self.batch_size = batch_size
    self.num_trees = num_trees
    self.max_nodes = max_nodes
    self.display_step = display_step

    # Input and Target data
    self.x = tf.placeholder(tf.float32, shape=[None, input_size])
    # For random forest, labels must be integers (the class id)
    self.y = tf.placeholder(tf.int32, shape=[None])

    # Random Forest Parameters
    self.hparams = tensor_forest.ForestHParams(num_classes=output_size,
                                  num_features=input_size,
                                  num_trees=self.num_trees,
                                  max_nodes=self.max_nodes).fill()

    # Build the Random Forest
    self.forest_graph = tensor_forest.RandomForestGraphs(self.hparams)
    # Get training graph and loss
    self.train = self.forest_graph.training_graph(self.x, self.y)
    self.loss = self.forest_graph.training_loss(self.x, self.y)

    # Measure the accuracy
    self.infer, _, _ = self.forest_graph.inference_graph(self.x)
    self.correct_pred = tf.equal(tf.argmax(self.infer, 1), tf.cast(self.y, tf.int64)
    self.accuracy = tf.reduce_mean(tf.cast(self.correct_pred, tf.float32))

    # Initialize the variables (i.e. assign their default value) and forest resource
    self.init = tf.group(tf.global_variables_initializer(),
        resources.initialize_resources(resources.shared_resources()))


def fit(self, sess = None):
    sessionCreated = False

    if sess is None:
        sess = tf.Session()
        sess.run(self.init)

        sessionCreated = True

    # Training
    for i in range(1, self.training_epochs + 1):
        # Prepare Data
        # Get the next batch of MNIST data (only images are needed, not labels)
```

```
                batch_x, batch_y = mnist.train.next_batch(self.batch_size)
                _, l = sess.run([self.train, self.loss], feed_dict={self.x: batch_x, self.y:

                if self.display_step >0 and (i % self.display_step == 0 or i == 1):
                    acc = sess.run(self.accuracy, feed_dict={self.x: batch_x, self.y: np.arg
                    print "Step {}, loss: {:.4f}, acc: {:.4f}".format(i+1, l, acc)


            if sessionCreated:
                sess.close()

        def measure_accuracy(self, sess=None):
            sessionCreated = False

            if sess is None:
                sess = tf.Session()
                sess.run(self.init)

                sessionCreated = True

            print "Test accuracy:", sess.run(self.accuracy,feed_dict = {self.x:mnist.test.im


            if sessionCreated:
                sess.close()
```

0.3 3. Train both models and achieve a "decent" testing accuracy (over 90%)

0.3.1 A: Logistic regression

```
In [11]: clf_reg = LogisticRegression(mnist.train.images.shape[1], 10, training_epochs=25, displ

         with tf.Session() as sess:
             # Run the initializer
             sess.run(clf_reg.init)

             clf_reg.fit(mnist.train.images, mnist.train.labels, sess)
             clf_reg.measure_accuracy(mnist.test.images, mnist.test.labels, sess)
```

```
Test accuracy: 0.9145
```

0.3.2 B: Convolutional Neural Network

```
In [12]: clf_cnn = CNN(mnist.train.images.shape[1], 10, display_step=0)

         with tf.Session() as sess:
             # Run the initializer
             sess.run(clf_cnn.init)
```

```
            clf_cnn.fit(mnist.train.images, mnist.train.labels, sess)
            clf_cnn.measure_accuracy(mnist.test.images, mnist.test.labels, sess)
```

```
Test accuracy: 0.95703125
```

C: Random forest

```
In [10]: clf_rf = RandomForest(mnist.train.images.shape[1], 10, training_epochs=500, display_ste
         with tf.Session() as sess:
             # Run the initializer
             sess.run(clf_rf.init)

             clf_rf.fit(sess)
             clf_rf.measure_accuracy(sess)
```

```
INFO:tensorflow:Constructing forest with params =
INFO:tensorflow:{'num_output_columns': 11, 'feature_bagging_fraction': 1.0, 'valid_leaf_threshol
Test accuracy: 0.9243
```

0.4 4. Generate 100 adversarial examples for each model

From the adversarial examples generated using both the models, we can see that Logistic regression model generates better adversarial examples compared to Convolutional Neural Network. In case of CNN we get higher accuracy for the test dataset. However, due to vanishing gradient, CNN causes no change to to input image based on which adversarial examples are generated.

Adversarial examples in case of CNN can be generated using very small number of epochs and training data. In that case the model is not trained well and it's prediction is not good for neither orginal image nor the adversarial example.

```
In [13]: # Helper function for visualization

         def show_images(images, labels, n, title="Label"):
             plt.figure(figsize=(20,4))
             for index, (image, label) in enumerate(zip(images[0:n], labels[0:n])):
                 plt.subplot(1, n, index + 1)
                 plt.imshow(np.reshape(image, (28,28)), cmap=plt.cm.gray)
                 plt.title('%s: %i\n' % (title, label), fontsize = 12)
             plt.show()

         def show_proba(images, labels, probabilities, n, title="Label"):
             plt.figure(figsize=(20,4))
             for index, (image, label, proba) in enumerate(zip(images[0:n], labels[0:n], probabi
                 plt.subplot(1, n, index + 1)

                 #y_proba = classifier.predict_proba([image])[0]
                 plt.bar(np.arange(10), proba)
```

```
            # print y_proba
            plt.title('%s: %i\n' % (title, label), fontsize = 12)
        plt.show()
```

0.4.1 A: Logistic regression

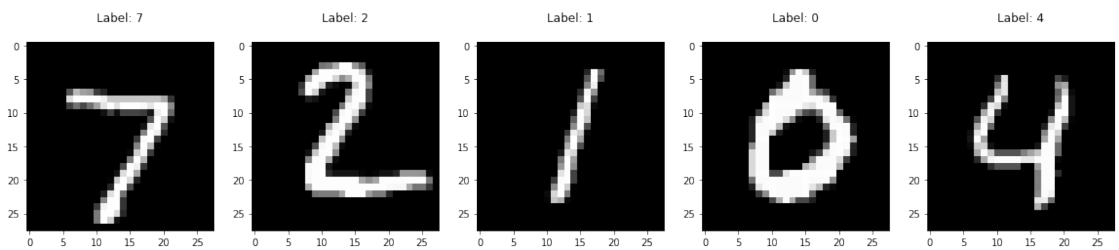
Generate 100 examples

```
In [14]: clf_reg = LogisticRegression(mnist.train.images.shape[1], 10, training_epochs=25, displ
         with tf.Session() as sess:
             # Run the initializer
             sess.run(clf_reg.init)

             clf_reg.fit(mnist.train.images, mnist.train.labels, sess)
             reg_pred_y, reg_adv_x, reg_adv_y = clf_reg.get_adversarial_images(mnist.test.images
                                                  mnist.test.labels[0:100], sess=sess)
```

Visualize 5 for analysis

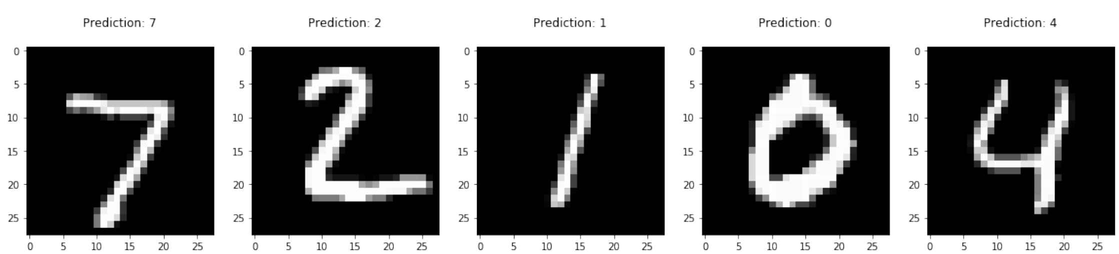
Actual labels

```
In [15]: show_images(mnist.test.images, np.argmax(mnist.test.labels, axis=1), 5)
```



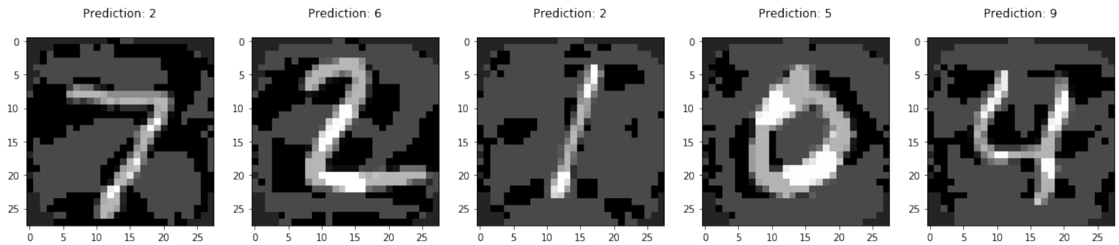
Predicted labels

```
In [16]: show_images(mnist.test.images[0:100], np.argmax(reg_pred_y, axis=1), 5, title="Predicti
```



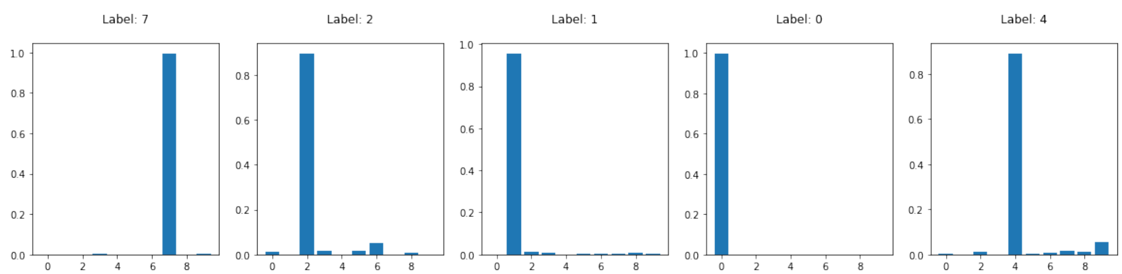
Adversarial images with predicted labels

```
In [17]: show_images(reg_adv_x, np.argmax(reg_adv_y, axis=1), 5, title="Prediction")
```



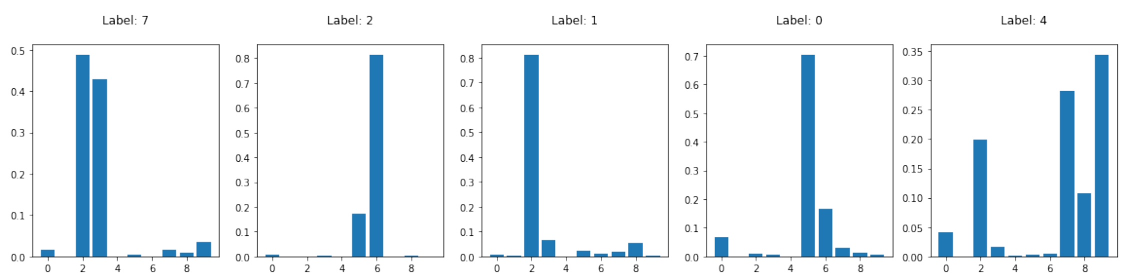
Probability for original images

```
In [18]: show_proba(mnist.test.images[0:100], np.argmax(mnist.test.labels[0:100], axis=1), reg_p
```



Probability for adversarial images

```
In [19]: show_proba(reg_adv_x, np.argmax(mnist.test.labels[0:100], axis=1), reg_adv_y, 5)
```



Accuracy for the adversarial images

```
In [21]: clf_reg = LogisticRegression(mnist.train.images.shape[1], 10, training_epochs=25, displ

         with tf.Session() as sess:
             # Run the initializer
             sess.run(clf_reg.init)

             clf_reg.fit(mnist.train.images, mnist.train.labels, sess)

             print "Adversarial accuracy:", sess.run(clf_reg.accuracy,
                             feed_dict = {clf_reg.x:reg_adv_x, clf_reg.y:mnist.test.labels[0:100
```

```
Adversarial accuracy: 0.0
```

0.4.2 B: Convolutional Neural Network

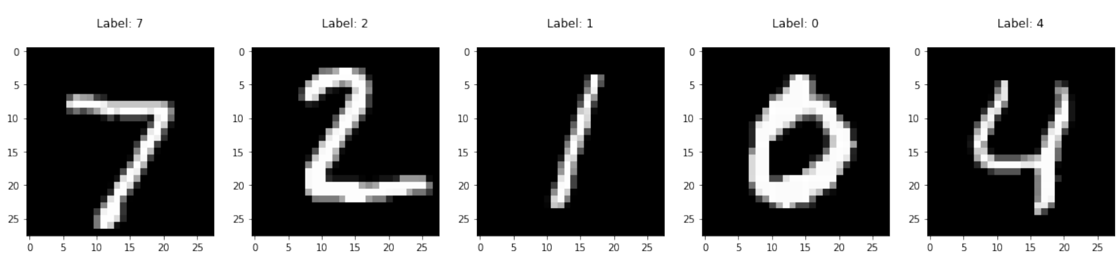
Generate 100 examples

```
In [23]: clf_cnn = CNN(mnist.train.images.shape[1], 10, training_epochs=1, display_step=0)

         with tf.Session() as sess:
             # Run the initializer
             sess.run(clf_cnn.init)

             clf_cnn.fit(mnist.train.images[0:2000], mnist.train.labels[0:2000], sess)
             cnn_pred_y, cnn_adv_x, cnn_adv_y = clf_cnn.get_adversarial_images(mnist.test.images
                                          mnist.test.labels[0:100], sess=sess)
```

Visualize 5 for analysis

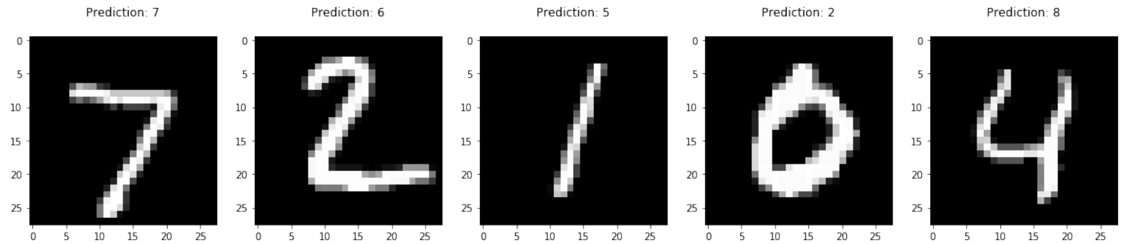
Actual labels

```
In [24]: show_images(mnist.test.images[0:100], np.argmax(mnist.test.labels, axis=1), 5)
```



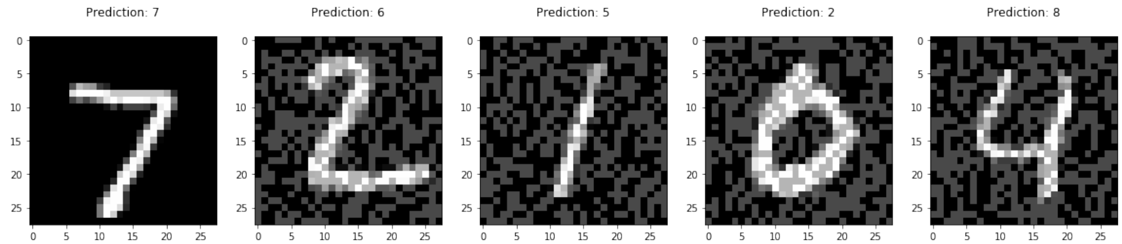
Predicted labels Most predictions are poor because the network was intentionaly trained with less data and for few epochs to generate adversarial examples

```
In [25]: show_images(mnist.test.images[0:100], np.argmax(cnn_pred_y, axis=1), 5, title="Predicti
```



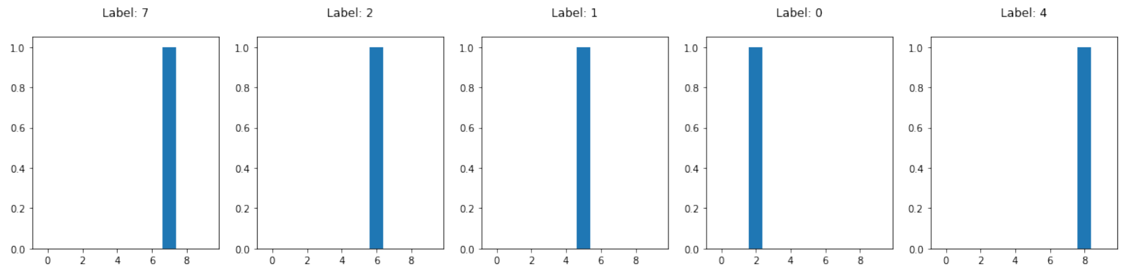
Adversarial images with predicted labels

```
In [26]: show_images(cnn_adv_x, np.argmax(cnn_adv_y, axis=1), 5, title="Prediction")
```



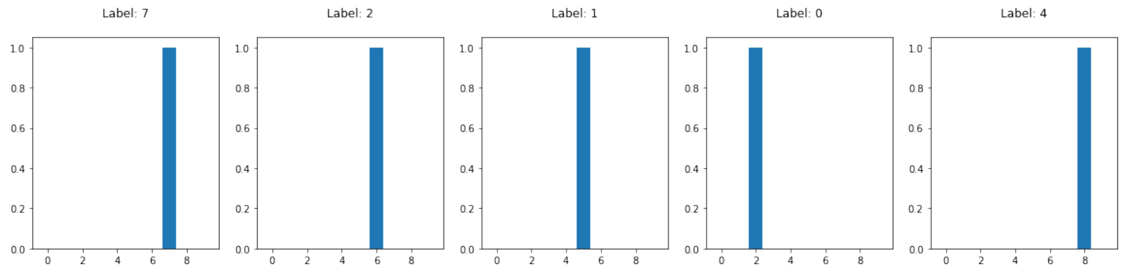
Probability for original image

```
In [27]: show_proba(mnist.test.images[0:100], np.argmax(mnist.test.labels[0:100], axis=1), cnn_p
```



Probability for adversarial images

```
In [28]: show_proba(cnn_adv_x, np.argmax(mnist.test.labels[0:100], axis=1), cnn_adv_y, 5)
```



Accuracy for the adversarial images

```
In [30]: clf_cnn = CNN(mnist.train.images.shape[1], 10, display_step=0)

         with tf.Session() as sess:
             # Run the initializer
             sess.run(clf_cnn.init)

             clf_cnn.fit(mnist.train.images, mnist.train.labels, sess)

             print "Adversarial accuracy:", sess.run(clf_cnn.accuracy,
                                 feed_dict = {clf_cnn.x:cnn_adv_x,
                                              clf_cnn.y:mnist.test.labels[0:100], clf_cnn.keep_prob:

Adversarial accuracy: 0.78
```

0.5 5. Use the adversarial examples of A with model B and of B with model A

The accuracy value below shows that the adversarial examples of Logistic regression fools Convolutional Neural Network but not vice versa. In the previous section we also found that accuracy of CNN for adversarial examples generated by itself is 78% whereas accuracy of Logistic regression for it's adversarial examples is zero.

0.5.1 Adversarial examples of Convolutional Neural Network used with Logistic regression

```
In [32]: clf_reg = LogisticRegression(mnist.train.images.shape[1], 10, training_epochs=25, displ

         with tf.Session() as sess:
             # Run the initializer
             sess.run(clf_reg.init)

             clf_reg.fit(mnist.train.images, mnist.train.labels, sess)
```

```
            print "Adversarial accuracy:", sess.run(clf_reg.accuracy,
                            feed_dict = {clf_reg.x:cnn_adv_x, clf_reg.y:mnist.test.labels[0:100
```

```
Adversarial accuracy: 0.95
```

0.5.2 Adversarial examples of Logistic regression used with Convolutional Neural Network

```
In [34]: clf_cnn = CNN(mnist.train.images.shape[1], 10, display_step=0)

         with tf.Session() as sess:
             # Run the initializer
             sess.run(clf_cnn.init)

             clf_cnn.fit(mnist.train.images, mnist.train.labels, sess)

             print "Adversarial accuracy:", sess.run(clf_cnn.accuracy,
                             feed_dict = {clf_cnn.x:reg_adv_x,
                                       clf_cnn.y:mnist.test.labels[0:100], clf_cnn.keep_prob:
```

```
Adversarial accuracy: 0.22
```

0.6 6. Generate new adversarial examples and evaluate

0.6.1 Generate new examples using Logistic regression

We used 1000 adversarial examples to reduce processing time

```
In [ ]: new_images = []
        new_labels = []

        clf_reg = LogisticRegression(mnist.train.images.shape[1], 10, training_epochs=25, displa

        with tf.Session() as sess:
            # Run the initializer
            sess.run(clf_reg.init)

            clf_reg.fit(mnist.train.images, mnist.train.labels, sess)

            for index, [image, label] in enumerate(zip(mnist.train.images[0:1000], mnist.train.l
                new_images.append(image)
                new_labels.append(label)

            for index, [image, label] in enumerate(zip(mnist.train.images, mnist.train.labels)):
                grad = sess.run([clf_reg.gradient_input], feed_dict = {
                    clf_reg.x:np.expand_dims(image, 0), clf_reg.y:np.expand_dims(label, 0)})
```

```
            adversarial_img_op = image + 0.2 * tf.sign(grad[0])
            adversarial_img = adversarial_img_op.eval(session=sess)


            new_images.append(adversarial_img[0])
            new_labels.append(label)
```

0.6.2 Evaluation with new adversarial examples

Logistic regression

```
In [51]: clf_reg = LogisticRegression(mnist.train.images.shape[1], 10, training_epochs=25, displ

         with tf.Session() as sess:
             # Run the initializer
             sess.run(clf_reg.init)

             clf_reg.fit(new_images, new_labels, sess)
             clf_reg.measure_accuracy(mnist.test.images, mnist.test.labels, sess)
```

```
Test accuracy: 0.9069
```

Convolutional Neural Network

```
In [52]: clf_cnn = CNN(mnist.train.images.shape[1], 10, display_step=0)

         with tf.Session() as sess:
             # Run the initializer
             sess.run(clf_cnn.init)

             clf_cnn.fit(new_images, new_labels, sess)
             clf_cnn.measure_accuracy(mnist.test.images, mnist.test.labels, sess)
```

```
Test accuracy: 0.91015625
```

- The evaluation above shows that the classification accuracy decreases for both the models in case of adversarial examples added in training set. This happens because the models tend to overfit.
- The model is less susceptible to adversarial examples after training with new examples.
- Yes we can do regularization to avoid overfitting. The CNN model uses dropout for regularization.