dropout

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1 Dropout

Dropout [1] is a technique for regularizing neural networks by randomly setting some features to zero during the forward pass. In this exercise you will implement a dropout layer and modify your fully-connected network to optionally use dropout.

[1] Geoffrey E. Hinton et al, "Improving neural networks by preventing co-adaptation of feature detectors", arXiv 2012

```
In [1]: import numpy as np
        import tensorflow as tf
        import matplotlib.pyplot as plt
        from data_utils import get_CIFAR10_data
        from implementations.layers import dropout_forward


        %matplotlib inline
        plt.rcParams['figure.figsize'] = (10.0, 8.0) # set default size of plots
        plt.rcParams['image.interpolation'] = 'nearest'
        plt.rcParams['image.cmap'] = 'gray'

        # for auto-reloading external modules
        # see http://stackoverflow.com/questions/1907993/autoreload-of-modules-in-ipython
        %load_ext autoreload
        %autoreload 2

        def rel_error(x, y):
          """ returns relative error """
          return np.max(np.abs(x - y) / (np.maximum(1e-8, np.abs(x) + np.abs(y))))
```

```
In [2]: # Load the (preprocessed) CIFAR10 data.

        data = get_CIFAR10_data()
        for k, v in data.items():
          print('%s: ' % k, v.shape)
```

```
y_train:  (49000,)
X_train:  (49000, 3, 32, 32)
```

```
X_test:  (1000, 3, 32, 32)
y_val:  (1000,)
y_test:  (1000,)
X_val:  (1000, 3, 32, 32)
```

2 Dropout in Tensorflow

Let's first try the dropout function in Tensorflow.

```
In [3]: np.random.seed(15009)
        x = np.random.randn(500, 500) + 10

        for p in [0.25, 0.4, 0.7]:

          # please read the documentation of tf.nn.dropout carefully
          out = tf.Session().run(tf.nn.dropout(x, keep_prob=p))

          print('Running tests with p = ', p)
          print('Mean of input: ', x.mean())
          print('Mean of train-time output: ', out.mean())
          print('Fraction of train-time output set to zero: ', (out == 0).mean())
          print()
```

```
Running tests with p =  0.25
Mean of input:  9.998768973493084
Mean of train-time output:  10.050682639183853
Fraction of train-time output set to zero:  0.748604

Running tests with p =  0.4
Mean of input:  9.998768973493084
Mean of train-time output:  10.028940242557937
Fraction of train-time output set to zero:  0.59872

Running tests with p =  0.7
Mean of input:  9.998768973493084
Mean of train-time output:  9.988007425313798
Fraction of train-time output set to zero:  0.30074
```

3 Dropout forward pass

In the file `implementations/layers.py`, implement the forward pass for dropout. Since dropout behaves differently during training and testing, make sure to implement the operation for both modes.

Once you have done so, run the cell below to test your implementation.

```
In [4]: np.random.seed(15009)
        x = np.random.randn(500, 500) + 10

        for p in [0.25, 0.4, 0.7]:
          out = dropout_forward(x, {'mode': 'train', 'p': p})

          # Hint: The tensorflow dropout does not have a mode parameter to specify the mode.
          out_test = dropout_forward(x, {'mode': 'test', 'p': p})

          print('Running tests with p = ', p)
          print('Mean of input: ', x.mean())
          print('Mean of train-time output: ', out.mean())
          print('Mean of test-time output: ', out_test.mean())
          print('Fraction of train-time output set to zero: ', (out == 0).mean())
          print('Fraction of test-time output set to zero: ', (out_test == 0).mean())
          print()
```

```
Running tests with p =  0.25
Mean of input:  9.998768973493084
Mean of train-time output:  9.969113372794604
Mean of test-time output:  9.998768973493084
Fraction of train-time output set to zero:  0.750668
Fraction of test-time output set to zero:  0.0

Running tests with p =  0.4
Mean of input:  9.998768973493084
Mean of train-time output:  10.00927915975404
Mean of test-time output:  9.998768973493084
Fraction of train-time output set to zero:  0.599568
Fraction of test-time output set to zero:  0.0

Running tests with p =  0.7
Mean of input:  9.998768973493084
Mean of train-time output:  9.997025369210016
Mean of test-time output:  9.998768973493084
Fraction of train-time output set to zero:  0.30024
Fraction of test-time output set to zero:  0.0
```

3.1 Inline Question 1:

What happens if we do not divide the values being passed through inverse dropout by p in the dropout layer? Why does that happen?

3.2 Answer:

The sum of the input weights to the next layer of nodes will be much less. This is because on average the magnitude of the sum of our weights should be p smaller since we lose p weights on average.

4 Fully-connected nets with Dropout

The assignment provides an implementation of fully connected neural network. You need to add dropout laytera to the implementation. *Now you can use* `tf.nn.dropout`.

Regularization experiment: As an experiment, we will train a pair of two-layer networks on 500 training examples: one will use no dropout, and one will use a keep probability of 0.25. We will then visualize the training and validation accuracies of the two networks over time.

```
In [3]: from implementations.fc_net import FullyConnectedNet

        # Train two identical nets, one with dropout and one without
        np.random.seed(15009)
        num_train = 500

        X_train = data['X_train'][:num_train]
        X_train = np.reshape(X_train, [X_train.shape[0], -1]) / 255
        y_train = data['y_train'][:num_train]
        X_val = data['X_val']
        X_val = np.reshape(X_val, [X_val.shape[0], -1]) / 255
        y_val = data['y_val']

        traces={}
        dropout_choices = [1, 0.25]
        for keep_prob in dropout_choices:
          model = FullyConnectedNet(input_size=X_train[0].size, hidden_size=[500], output_size



          train_trace= model.train(X=X_train, y=y_train, X_val=X_val, y_val=y_val,
                                   learning_rate=2e-3, keep_prob=keep_prob,
                                   reg=np.float32(5e-6), num_iters=1000,
                                   batch_size=32, verbose=True)

          traces[keep_prob] = train_trace
```

```
WARNING:tensorflow:From /Users/alanzhou/Documents/comp150/comp150a2/implementations/fc_net.py:
Instructions for updating:

Future major versions of TensorFlow will allow gradients to flow
into the labels input on backprop by default.

See @{tf.nn.softmax_cross_entropy_with_logits_v2}.

iteration 0 / 1000: objective 74.464775
iteration 100 / 1000: objective 43.078403
iteration 200 / 1000: objective 32.892120
iteration 300 / 1000: objective 17.114698
iteration 400 / 1000: objective 14.227289
iteration 500 / 1000: objective 21.940378
iteration 600 / 1000: objective 3.831016
iteration 700 / 1000: objective 3.938713
iteration 800 / 1000: objective 2.005296
iteration 900 / 1000: objective 2.123274
iteration 0 / 1000: objective 72.737442
iteration 100 / 1000: objective 47.916592
iteration 200 / 1000: objective 40.206795
iteration 300 / 1000: objective 30.404478
iteration 400 / 1000: objective 29.459522
iteration 500 / 1000: objective 36.582508
iteration 600 / 1000: objective 21.210480
iteration 700 / 1000: objective 14.502404
iteration 800 / 1000: objective 12.213260
iteration 900 / 1000: objective 9.215892
```

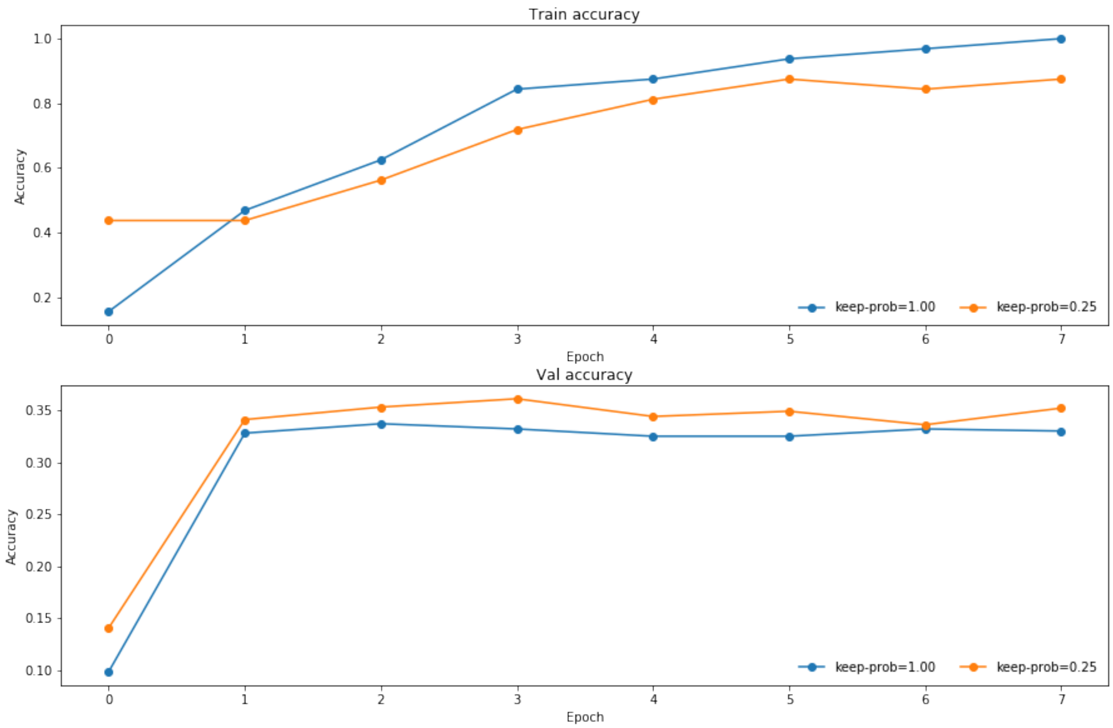
```
In [26]: # Plot train and validation accuracies of the two models

         train_accs = []
         val_accs = []
         for keep_prob in dropout_choices:
           trace = traces[keep_prob]
           train_accs.append(trace['train_acc_history'][-1])
           val_accs.append(trace['val_acc_history'][-1])

         plt.subplot(3, 1, 1)
         for keep_prob in dropout_choices:
           plt.plot(traces[keep_prob]['train_acc_history'], '-o', label='keep-prob=%.2f' % kee
         plt.title('Train accuracy')
         plt.xlabel('Epoch')
         plt.ylabel('Accuracy')
         plt.legend(ncol=2, loc='lower right')

         plt.subplot(3, 1, 2)
         for keep_prob in dropout_choices:
           plt.plot(traces[keep_prob]['val_acc_history'], '-o', label='keep-prob=%.2f' % keep_
         plt.title('Val accuracy')
         plt.xlabel('Epoch')
         plt.ylabel('Accuracy')
         plt.legend(ncol=2, loc='lower right')

         plt.gcf().set_size_inches(15, 15)
         plt.show()
```



4.1 Inline Question 2:

Compare the validation and training accuracies with and without dropout – what do your results suggest about dropout as a regularizer?

4.2 Answer:

Dropout acts similarly to other standard forms of regularization by preventing overfitting. We can see this in our results as using dropout decreases our training accuracy but increases our validation accuracy.

4.3 Inline Question 3:

Suppose we are training a deep fully-connected network for image classification, with dropout after hidden layers (parameterized by keep probability p). How should we modify p, if at all, if we decide to decrease the size of the hidden layers (that is, the number of nodes in each layer)?

4.4 Answer:

If we decrease the size of the hidden layers we may want to increase p, since decreasing the number of hidden layers decreases our model space. If we want to avoid too drastically decreasing our model space, we can somewhat compensate for that by increasing p, which brings our model space back up with fewer nodes dropped on average in each dropout layer.