softmax

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1 Softmax Classifier

This exercise guides you through the process of classifying images using a Softmax classifier. As part of this you will:

- Implement a fully vectorized loss function for the Softmax classifier
- Calculate the analytical gradient using vectorized code
- Tune hyperparameters on a validation set
- Optimize the loss function with Stochastic Gradient Descent (SGD)
- Visualize the learned weights

```
In [1]: # start-up code!
        import random

        import matplotlib.pyplot as plt
        import numpy as np

        %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 extenrnal modules
        # see http://stackoverflow.com/questions/1907993/autoreload-of-modules-in-ipython
        %load_ext autoreload
        %autoreload 2
```

```
In [2]: from load_cifar10_tvt import load_cifar10_train_val

        X_train, y_train, X_val, y_val, X_test, y_test = load_cifar10_train_val()
        print("Train data shape: ", X_train.shape)
        print("Train labels shape: ", y_train.shape)
        print("Val data shape: ", X_val.shape)
        print("Val labels shape: ", y_val.shape)
        print("Test data shape: ", X_test.shape)
        print("Test labels shape: ", y_test.shape)
```

```
Train, validation and testing sets have been created as
 X_i and y_i where i=train,val,test
Train data shape:  (3073, 49000)
Train labels shape:  (49000,)
Val data shape:  (3073, 1000)
Val labels shape:  (1000,)
Test data shape:  (3073, 1000)
Test labels shape:  (1000,)
```

Code for this section is to be written in cs231n/classifiers/softmax.py

```
In [9]: # Now, implement the vectorized version in softmax_loss_vectorized.

        import time

        from cs231n.classifiers.softmax import softmax_loss_vectorized

        # gradient check.
        from cs231n.gradient_check import grad_check_sparse

        W = np.random.randn(10, 3073) * 0.0001

        tic = time.time()
        loss, grad = softmax_loss_vectorized(W, X_train, y_train, 0.00001)
        toc = time.time()
        print("vectorized loss: %e computed in %fs" % (loss, toc - tic))

        # As a rough sanity check, our loss should be something close to -log(0.1).
        print("loss: %f" % loss)
        print("sanity check: %f" % (-np.log(0.1)))

        f = lambda w: softmax_loss_vectorized(w, X_train, y_train, 0.0)[0]
        grad_numerical = grad_check_sparse(f, W, grad, 10)
```

```
vectorized loss: 2.358837e+00 computed in 0.625360s
loss: 2.358837
sanity check: 2.302585
numerical: 1.897609 analytic: 1.897361, relative error: 6.550134e-05
numerical: -1.387101 analytic: -1.387062, relative error: 1.401846e-05
numerical: 3.547049 analytic: 3.546799, relative error: 3.526429e-05
numerical: 1.427716 analytic: 1.427785, relative error: 2.413449e-05
numerical: 1.067347 analytic: 1.066835, relative error: 2.399849e-04
numerical: 0.339480 analytic: 0.339402, relative error: 1.148107e-04
numerical: 1.035761 analytic: 1.035384, relative error: 1.821086e-04
numerical: -1.030169 analytic: -1.030336, relative error: 8.081725e-05
numerical: -2.182639 analytic: -2.182752, relative error: 2.577810e-05
numerical: 1.464362 analytic: 1.463994, relative error: 1.256691e-04
```

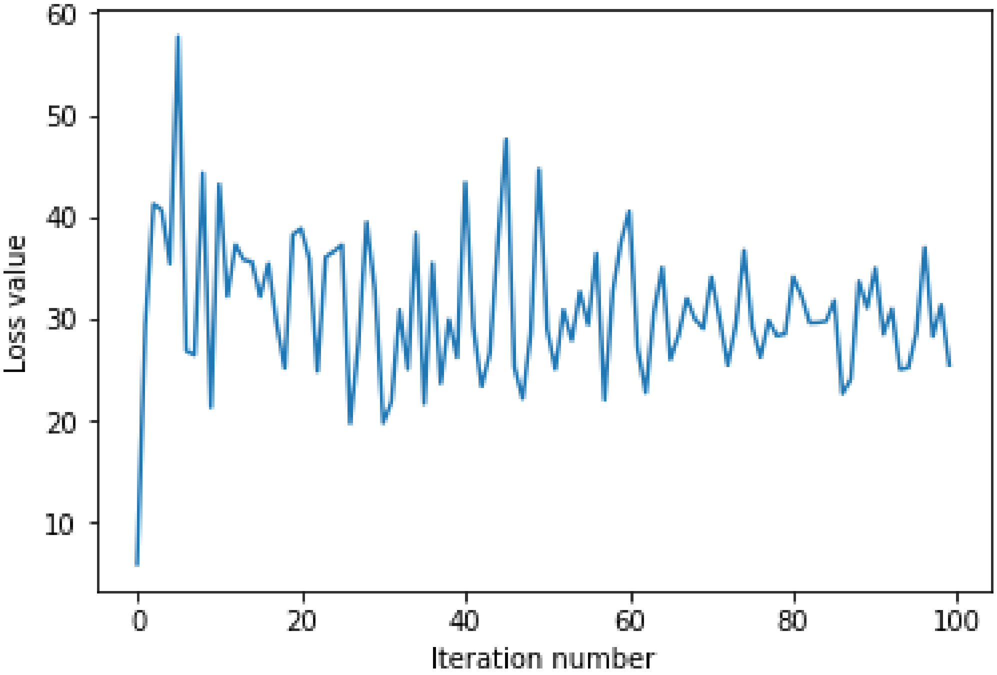
Code for this section is to be written incs231n/classifiers/linear_classifier.py

```
In [65]: # Now that efficient implementations to calculate loss function and gradient of the s
         # use it to train the classifier on the cifar-10 data
         # Complete the `train` function in cs231n/classifiers/linear_classifier.py

         from cs231n.classifiers.linear_classifier import Softmax

         classifier = Softmax()
         loss_hist = classifier.train(
             X_train,
             y_train,
             learning_rate=1e-4,
             reg=1e-4,
             num_iters=100,
             batch_size=2000,
             verbose=False,
         )
         # Plot loss vs. iterations
         plt.plot(loss_hist)
         plt.xlabel("Iteration number")
         plt.ylabel("Loss value")
```

```
Out[65]: Text(0,0.5,'Loss value')
```



```
In [66]: # Complete the `predict` function in cs231n/classifiers/linear_classifier.py
         # Evaluate on test set
         y_test_pred = classifier.predict(X_test)
         test_accuracy = np.mean(y_test == y_test_pred)
         print("softmax on raw pixels final test set accuracy: %f" % (test_accuracy,))
```

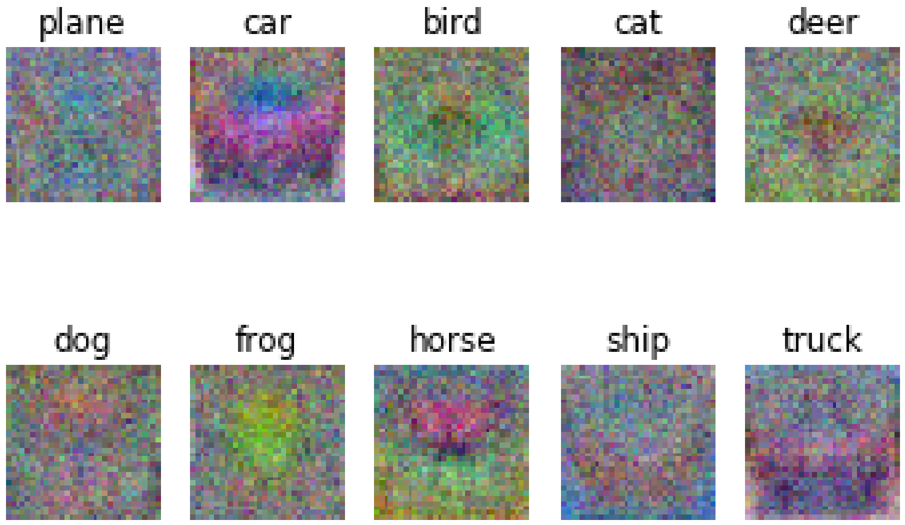
```
softmax on raw pixels final test set accuracy: 0.268000
```

```
In [67]: # Visualize the learned weights for each class
         w = classifier.W[:, :-1]  # strip out the bias
         w = w.reshape(10, 32, 32, 3)

         w_min, w_max = np.min(w), np.max(w)

         classes = [
             "plane",
             "car",
             "bird",
             "cat",
             "deer",
             "dog",
             "frog",
             "horse",
             "ship",
             "truck",
         ]
         for i in range(10):
             plt.subplot(2, 5, i + 1)

             # Rescale the weights to be between 0 and 255
             wimg = 255.0 * (w[i].squeeze() - w_min) / (w_max - w_min)
             plt.imshow(wimg.astype("uint8"))
             plt.axis("off")
             plt.title(classes[i])
```



```
In [ ]:
```