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 [3]:
```
# 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: 2.382422e+00 computed in 0.585892s
loss: 2.382422
sanity check: 2.302585
numerical: -4.046185 analytic: -4.046185, relative error: 9.531160e-09
numerical: -1.985439 analytic: -1.985439, relative error: 1.308065e-09
numerical: -1.685963 analytic: -1.685963, relative error: 3.072309e-09
numerical: -0.192502 analytic: -0.192502, relative error: 4.025777e-07
numerical: -1.057372 analytic: -1.057372, relative error: 1.039151e-08
numerical: -2.068152 analytic: -2.068152, relative error: 5.768658e-09
numerical: 1.733033 analytic: 1.733033, relative error: 2.407816e-08
numerical: 0.965264 analytic: 0.965264, relative error: 6.165870e-08
numerical: 0.956019 analytic: 0.956019, relative error: 2.961977e-08
```

```
numerical: -3.049205 analytic: -3.049205, relative error: 2.257660e-10
```

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

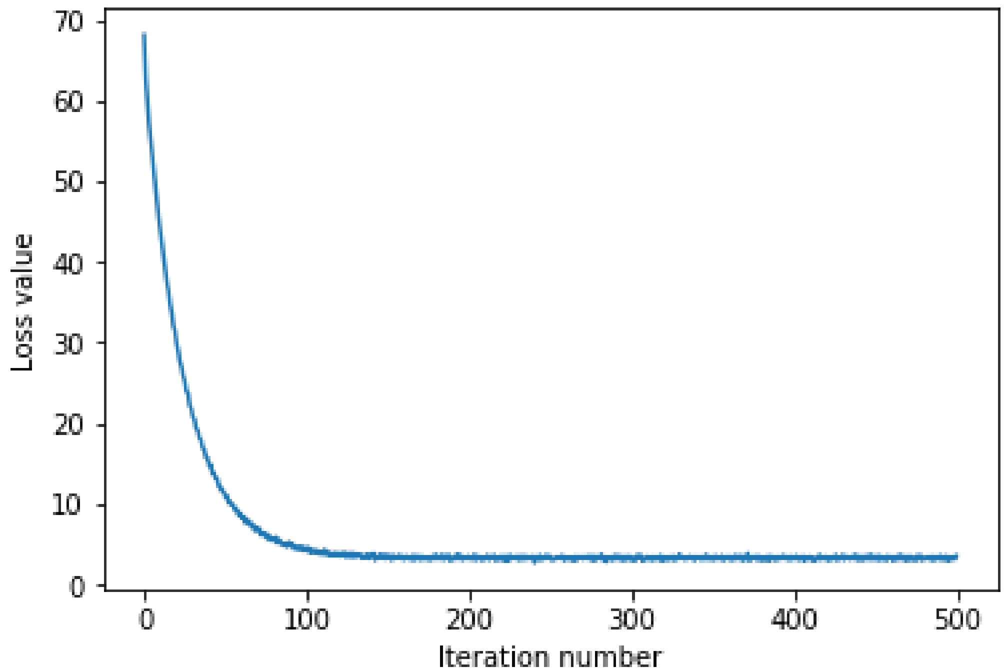
```
In [27]: # Now that efficient implementations to calculate loss function and gradient of the s
         # use it to train the classifier on the cifar-10 data
         # Complete the `train` function in cs231n/classifiers/linear_classifier.py

         from cs231n.classifiers.linear_classifier import Softmax

         classifier = Softmax()
         loss_hist = classifier.train(
             X_train,
             y_train,
             learning_rate=1e-5,
             reg=2000,
             num_iters=500,
             batch_size=8000,
             verbose=True,
         )
         # Plot loss vs. iterations
         plt.plot(loss_hist)
         plt.xlabel("Iteration number")
         plt.ylabel("Loss value")
```

```
iteration 0 / 500: loss 68.132452
iteration 100 / 500: loss 4.206699
iteration 200 / 500: loss 3.127493
iteration 300 / 500: loss 2.996467
iteration 400 / 500: loss 3.226845
```

```
Out[27]: Text(0,0.5,'Loss value')
```




```
In [28]: # 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: 0.254000
```

```
In [29]: # 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])
```