# 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 externral 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: 2.344749e+00 computed in 0.257661s
loss: 2.344749
sanity check: 2.302585
numerical: 1.965265 analytic: 1.965265, relative error: 4.050525e-08
numerical: 4.230704 analytic: 4.230704, relative error: 1.309142e-08
numerical: -0.892266 analytic: -0.892266, relative error: 5.395355e-08
numerical: 2.159850 analytic: 2.159850, relative error: 6.890465e-09
numerical: 0.289739 analytic: 0.289739, relative error: 1.286889e-07
numerical: -0.882801 analytic: -0.882801, relative error: 5.561869e-08
numerical: 2.027293 analytic: 2.027293, relative error: 1.478793e-08
numerical: -0.146122 analytic: -0.146122, relative error: 3.984646e-07
numerical: -0.920213 analytic: -0.920213, relative error: 4.301624e-08
numerical: -2.725859 analytic: -2.725859, relative error: 3.388619e-08
```

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

In [4]:

```python
# Now that efficient implementations to calculate loss function and gradient of the softmax are ready,
# 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=1e-5,
    num_iters=100,
    batch_size=200,
    verbose=True,
)
# Plot loss vs. iterations
plt.plot(loss_hist)
plt.xlabel("Iteration number")
plt.ylabel("Loss value")
```

```
found batch.
loss + grad computed.
weights updated.
iteration 0 / 100: loss 6.316712
found batch.
loss + grad computed.
weights updated.
found batch.
loss + grad computed.
weights updated.
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weights updated.
iteration 10 / 100: loss 3.519489
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iteration 20 / 100: loss 3.028383
found batch.
loss + grad computed.
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iteration 30 / 100: loss 2.901936
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loss + grad computed.
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found batch.
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iteration 40 / 100: loss 3.395893
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iteration 50 / 100: loss 3.307890
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iteration 60 / 100: loss 3.959330
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iteration 70 / 100: loss 3.508856
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iteration 80 / 100: loss 3.023361
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weights updated.
iteration 90 / 100: loss 2.433835
found batch.
loss + grad computed.
weights updated.
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loss + grad computed.
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weights updated.
found batch.
loss + grad computed.
weights updated.
```
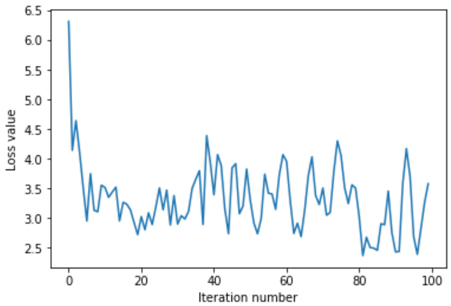

Out[4]:
```
Text(0,0.5,'Loss value')
```



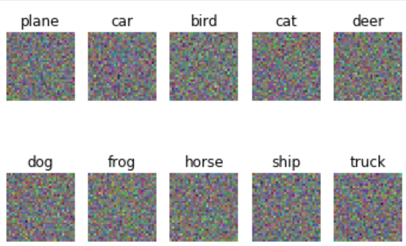

In [5]:

```
# 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: 0.273000
```

In [6]:

```
# 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 [ ]: