Image features exercise

Complete and hand in this completed worksheet (including its outputs and any supporting code outside of the worksheet) with your assignment submission. For more details see the [assignments page (https://compsci682-fa19.github.io/assignments2019/assignment1)](https://compsci682-fa19.github.io/assignments2019/assignment1) *on the course website.*

We have seen that we can achieve reasonable performance on an image classification task by training a linear classifier on the pixels of the input image. In this exercise we will show that we can improve our classification performance by training linear classifiers not on raw pixels but on features that are computed from the raw pixels.

All of your work for this exercise will be done in this notebook.

```
In [1]:  from __future__ import print_function
         import random
         import numpy as np
         from cs682.data_utils import load_CIFAR10
         import matplotlib.pyplot as plt


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

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

Load data

Similar to previous exercises, we will load CIFAR-10 data from disk.

```python
In [2]: from cs682.features import color_histogram_hsv, hog_feature

        def get_CIFAR10_data(num_training=49000, num_validation=1000, num_tes
        t=1000):
            # Load the raw CIFAR-10 data
            cifar10_dir = 'cs682/datasets/cifar-10-batches-py'

            X_train, y_train, X_test, y_test = load_CIFAR10(cifar10_dir)

            # Subsample the data
            mask = list(range(num_training, num_training + num_validation))
            X_val = X_train[mask]
            y_val = y_train[mask]
            mask = list(range(num_training))
            X_train = X_train[mask]
            y_train = y_train[mask]
            mask = list(range(num_test))
            X_test = X_test[mask]
            y_test = y_test[mask]

            return X_train, y_train, X_val, y_val, X_test, y_test

        # Cleaning up variables to prevent loading data multiple times (which
        may cause memory issue)
        try:
           del X_train, y_train
           del X_test, y_test
           print('Clear previously loaded data.')
        except:
           pass

        X_train, y_train, X_val, y_val, X_test, y_test = get_CIFAR10_data()
```

Extract Features

For each image we will compute a Histogram of Oriented Gradients (HOG) as well as a color histogram using the hue channel in HSV color space. We form our final feature vector for each image by concatenating the HOG and color histogram feature vectors.

Roughly speaking, HOG should capture the texture of the image while ignoring color information, and the color histogram represents the color of the input image while ignoring texture. As a result, we expect that using both together ought to work better than using either alone. Verifying this assumption would be a good thing to try for your interests.

The `hog_feature` and `color_histogram_hsv` functions both operate on a single image and return a feature vector for that image. The extract_features function takes a set of images and a list of feature functions and evaluates each feature function on each image, storing the results in a matrix where each column is the concatenation of all feature vectors for a single image.

In [3]:
```python
from cs682.features import *

num_color_bins = 10 # Number of bins in the color histogram
feature_fns = [hog_feature, lambda img: color_histogram_hsv(img, nbin
=num_color_bins)]
X_train_feats = extract_features(X_train, feature_fns, verbose=True)
X_val_feats = extract_features(X_val, feature_fns)
X_test_feats = extract_features(X_test, feature_fns)

# Preprocessing: Subtract the mean feature
mean_feat = np.mean(X_train_feats, axis=0, keepdims=True)
X_train_feats -= mean_feat
X_val_feats -= mean_feat
X_test_feats -= mean_feat

# Preprocessing: Divide by standard deviation. This ensures that each
feature
# has roughly the same scale.
std_feat = np.std(X_train_feats, axis=0, keepdims=True)
X_train_feats /= std_feat
X_val_feats /= std_feat
X_test_feats /= std_feat

# Preprocessing: Add a bias dimension
X_train_feats = np.hstack([X_train_feats, np.ones((X_train_feats.shap
e[0], 1))])
X_val_feats = np.hstack([X_val_feats, np.ones((X_val_feats.shape[0],
1))])
X_test_feats = np.hstack([X_test_feats, np.ones((X_test_feats.shape[0
], 1))])
```

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Done extracting features for 48000 / 49000 images
```

Train SVM on features

Using the multiclass SVM code developed earlier in the assignment, train SVMs on top of the features extracted above; this should achieve better results than training SVMs directly on top of raw pixels.

In [4]:
```python
# Use the validation set to tune the learning rate and regularization
strength

from cs682.classifiers.linear_classifier import LinearSVM

learning_rates = [1e-9, 1e-8, 1e-7]
regularization_strengths = [5e4, 5e5, 5e6]

results = {}
best_val = -1
best_svm = None

################################################################################
###########
# TODO:
#
# Use the validation set to set the learning rate and regularization
  strength. #
# This should be identical to the validation that you did for the SV
M; save      #
# the best trained classifer in best_svm. You might also want to play
#
# with different numbers of bins in the color histogram. If you are c
areful      #
# you should be able to get accuracy of near 0.44 on the validation s
et.         #
################################################################################
###########
learning_rates = [1e-9, 5e-5]
regularization_strengths = [2e4, 5e6]
num_iters = 20
for it in range(num_iters):
    for jt in range(num_iters):
        svm = LinearSVM()
        learning_rate = learning_rates[0] + it * ((learning_rates[1]
- learning_rates[0]) / num_iters)
        reg = regularization_strengths[0] + jt * ((regularization_str
engths[1] - regularization_strengths[0])/ num_iters)
        loss_hist = svm.train(X_train_feats, y_train, learning_rate=l
earning_rate, reg=reg,
                              num_iters=3000, verbose=False)
        y_train_pred = svm.predict(X_train_feats)
        y_val_pred = svm.predict(X_val_feats)
        training_accuracy = np.mean(y_train == y_train_pred)
        validation_accuracy = np.mean(y_val == y_val_pred)
        results[(learning_rate, reg)] = (training_accuracy, validatio
n_accuracy)
        print('lr %e reg %e  train accuracy: %f val accuracy: %f' % (
                    learning_rate, reg, training_accuracy, validation
_accuracy))
        if validation_accuracy > best_val:
            best_val = validation_accuracy
            best_svm = svm

################################################################################
###########
```

```
#                                  END OF YOUR CODE
#
##########################################################################
###########

# Print out results.
for lr, reg in sorted(results):
    train_accuracy, val_accuracy = results[(lr, reg)]
    print('lr %e reg %e train accuracy: %f val accuracy: %f' % (
                lr, reg, train_accuracy, val_accuracy))

print('best validation accuracy achieved during cross-validation: %f'
% best_val)
```

```
lr 1.000000e-09 reg 2.000000e+04  train accuracy: 0.096755 val accura
cy: 0.088000
lr 1.000000e-09 reg 2.690000e+05  train accuracy: 0.119918 val accura
cy: 0.098000
lr 1.000000e-09 reg 5.180000e+05  train accuracy: 0.085653 val accura
cy: 0.081000
lr 1.000000e-09 reg 7.670000e+05  train accuracy: 0.090796 val accura
cy: 0.090000
lr 1.000000e-09 reg 1.016000e+06  train accuracy: 0.098673 val accura
cy: 0.092000
lr 1.000000e-09 reg 1.265000e+06  train accuracy: 0.181918 val accura
cy: 0.163000
lr 1.000000e-09 reg 1.514000e+06  train accuracy: 0.331490 val accura
cy: 0.353000
lr 1.000000e-09 reg 1.763000e+06  train accuracy: 0.403327 val accura
cy: 0.398000
lr 1.000000e-09 reg 2.012000e+06  train accuracy: 0.416041 val accura
cy: 0.415000
lr 1.000000e-09 reg 2.261000e+06  train accuracy: 0.415449 val accura
cy: 0.417000
lr 1.000000e-09 reg 2.510000e+06  train accuracy: 0.413837 val accura
cy: 0.418000
lr 1.000000e-09 reg 2.759000e+06  train accuracy: 0.417020 val accura
cy: 0.423000
lr 1.000000e-09 reg 3.008000e+06  train accuracy: 0.412306 val accura
cy: 0.418000
lr 1.000000e-09 reg 3.257000e+06  train accuracy: 0.417163 val accura
cy: 0.416000
lr 1.000000e-09 reg 3.506000e+06  train accuracy: 0.417347 val accura
cy: 0.415000
lr 1.000000e-09 reg 3.755000e+06  train accuracy: 0.413531 val accura
cy: 0.418000
lr 1.000000e-09 reg 4.004000e+06  train accuracy: 0.413306 val accura
cy: 0.411000
lr 1.000000e-09 reg 4.253000e+06  train accuracy: 0.414204 val accura
cy: 0.419000
lr 1.000000e-09 reg 4.502000e+06  train accuracy: 0.416224 val accura
cy: 0.417000
lr 1.000000e-09 reg 4.751000e+06  train accuracy: 0.415939 val accura
cy: 0.416000
lr 2.500950e-06 reg 2.000000e+04  train accuracy: 0.397388 val accura
cy: 0.402000
lr 2.500950e-06 reg 2.690000e+05  train accuracy: 0.300714 val accura
cy: 0.292000
```

```
/home/nikhil/Desktop/git_workspace/Neural-Networks/assignment1/cs682/
classifiers/linear_svm.py:92: RuntimeWarning: overflow encountered in
double_scalars
  loss += reg * np.sum(W * W)
/home/nikhil/anaconda3/lib/python3.7/site-packages/numpy/core/fromnum
eric.py:86: RuntimeWarning: overflow encountered in reduce
  return ufunc.reduce(obj, axis, dtype, out, **passkwargs)
/home/nikhil/Desktop/git_workspace/Neural-Networks/assignment1/cs682/
classifiers/linear_svm.py:92: RuntimeWarning: overflow encountered in
multiply
  loss += reg * np.sum(W * W)
/home/nikhil/Desktop/git_workspace/Neural-Networks/assignment1/cs682/
classifiers/linear_svm.py:116: RuntimeWarning: overflow encountered i
n multiply
  dW += 2 * reg * W
/home/nikhil/Desktop/git_workspace/Neural-Networks/assignment1/cs682/
classifiers/linear_svm.py:87: RuntimeWarning: invalid value encounter
ed in subtract
  diffs = scores.T - actuals + 1 #(10*500)
/home/nikhil/Desktop/git_workspace/Neural-Networks/assignment1/cs682/
classifiers/linear_svm.py:88: RuntimeWarning: invalid value encounter
ed in less
  diffs[np.where(diffs < 0)] = 0
/home/nikhil/Desktop/git_workspace/Neural-Networks/assignment1/cs682/
classifiers/linear_svm.py:109: RuntimeWarning: invalid value encounte
red in greater
  diffs[np.where(diffs > 0)] = 1 #(10*500)
```

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lr 2.500950e-06 reg 5.180000e+05   train accuracy: 0.100265 val accura
cy: 0.087000
lr 2.500950e-06 reg 7.670000e+05   train accuracy: 0.100265 val accura
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                    cy: 0.087000
          lr 1.250075e-05 reg 4.751000e+06  train accuracy: 0.100265 val accura
                    cy: 0.087000
          lr 1.500070e-05 reg 2.000000e+04  train accuracy: 0.357061 val accura
                    cy: 0.349000
          lr 1.500070e-05 reg 2.690000e+05  train accuracy: 0.100265 val accura
                    cy: 0.087000
          lr 1.500070e-05 reg 5.180000e+05  train accuracy: 0.100265 val accura
                    cy: 0.087000
          lr 1.500070e-05 reg 7.670000e+05  train accuracy: 0.100265 val accura
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          lr 1.500070e-05 reg 1.514000e+06  train accuracy: 0.100265 val accura
                    cy: 0.087000
          lr 1.500070e-05 reg 1.763000e+06  train accuracy: 0.100265 val accura
                    cy: 0.087000
          lr 1.500070e-05 reg 2.012000e+06  train accuracy: 0.100265 val accura
                    cy: 0.087000
          lr 1.500070e-05 reg 2.261000e+06  train accuracy: 0.100265 val accura
                    cy: 0.087000
          lr 1.500070e-05 reg 2.510000e+06  train accuracy: 0.100265 val accura
                    cy: 0.087000
          lr 1.500070e-05 reg 2.759000e+06  train accuracy: 0.100265 val accura
                    cy: 0.087000
          lr 1.500070e-05 reg 3.008000e+06  train accuracy: 0.100265 val accura
                    cy: 0.087000
          lr 1.500070e-05 reg 3.257000e+06  train accuracy: 0.100265 val accura
                    cy: 0.087000
          lr 1.500070e-05 reg 3.506000e+06  train accuracy: 0.100265 val accura
                    cy: 0.087000
          lr 1.500070e-05 reg 3.755000e+06  train accuracy: 0.100265 val accura
                    cy: 0.087000
```

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lr 1.500070e-05 reg 4.004000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 1.500070e-05 reg 4.253000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 1.500070e-05 reg 4.502000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 1.500070e-05 reg 4.751000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 1.750065e-05 reg 2.000000e+04  train accuracy: 0.342980 val accura
cy: 0.357000
lr 1.750065e-05 reg 2.690000e+05  train accuracy: 0.100265 val accura
cy: 0.087000
lr 1.750065e-05 reg 5.180000e+05  train accuracy: 0.100265 val accura
cy: 0.087000
lr 1.750065e-05 reg 7.670000e+05  train accuracy: 0.100265 val accura
cy: 0.087000
lr 1.750065e-05 reg 1.016000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 1.750065e-05 reg 1.265000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 1.750065e-05 reg 1.514000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 1.750065e-05 reg 1.763000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 1.750065e-05 reg 2.012000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 1.750065e-05 reg 2.261000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 1.750065e-05 reg 2.510000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 1.750065e-05 reg 2.759000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 1.750065e-05 reg 3.008000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 1.750065e-05 reg 3.257000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 1.750065e-05 reg 3.506000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 1.750065e-05 reg 3.755000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 1.750065e-05 reg 4.004000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 1.750065e-05 reg 4.253000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 1.750065e-05 reg 4.502000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 1.750065e-05 reg 4.751000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 2.000060e-05 reg 2.000000e+04  train accuracy: 0.356714 val accura
cy: 0.371000
lr 2.000060e-05 reg 2.690000e+05  train accuracy: 0.100265 val accura
cy: 0.087000
lr 2.000060e-05 reg 5.180000e+05  train accuracy: 0.100265 val accura
cy: 0.087000
lr 2.000060e-05 reg 7.670000e+05  train accuracy: 0.100265 val accura
cy: 0.087000
lr 2.000060e-05 reg 1.016000e+06  train accuracy: 0.100265 val accura
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                    cy: 0.087000
                    lr 2.000060e-05 reg 1.265000e+06  train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 2.000060e-05 reg 1.514000e+06  train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 2.000060e-05 reg 1.763000e+06  train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 2.000060e-05 reg 2.012000e+06  train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 2.000060e-05 reg 2.261000e+06  train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 2.000060e-05 reg 2.510000e+06  train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 2.000060e-05 reg 2.759000e+06  train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 2.000060e-05 reg 3.008000e+06  train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 2.000060e-05 reg 3.257000e+06  train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 2.000060e-05 reg 3.506000e+06  train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 2.000060e-05 reg 3.755000e+06  train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 2.000060e-05 reg 4.004000e+06  train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 2.000060e-05 reg 4.253000e+06  train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 2.000060e-05 reg 4.502000e+06  train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 2.000060e-05 reg 4.751000e+06  train accuracy: 0.100265 val accura
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                    cy: 0.087000
                    lr 2.250055e-05 reg 7.670000e+05  train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 2.250055e-05 reg 1.016000e+06  train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 2.250055e-05 reg 1.265000e+06  train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 2.250055e-05 reg 1.514000e+06  train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 2.250055e-05 reg 1.763000e+06  train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 2.250055e-05 reg 2.012000e+06  train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 2.250055e-05 reg 2.261000e+06  train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 2.250055e-05 reg 2.510000e+06  train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 2.250055e-05 reg 2.759000e+06  train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 2.250055e-05 reg 3.008000e+06  train accuracy: 0.100265 val accura
                    cy: 0.087000
```

```
          lr 2.250055e-05 reg 3.257000e+06  train accuracy: 0.100265 val accura
          cy: 0.087000
          lr 2.250055e-05 reg 3.506000e+06  train accuracy: 0.100265 val accura
          cy: 0.087000
          lr 2.250055e-05 reg 3.755000e+06  train accuracy: 0.100265 val accura
          cy: 0.087000
          lr 2.250055e-05 reg 4.004000e+06  train accuracy: 0.100265 val accura
          cy: 0.087000
          lr 2.250055e-05 reg 4.253000e+06  train accuracy: 0.100265 val accura
          cy: 0.087000
          lr 2.250055e-05 reg 4.502000e+06  train accuracy: 0.100265 val accura
          cy: 0.087000
          lr 2.250055e-05 reg 4.751000e+06  train accuracy: 0.100265 val accura
          cy: 0.087000
          lr 2.500050e-05 reg 2.000000e+04  train accuracy: 0.341510 val accura
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          lr 2.500050e-05 reg 2.690000e+05  train accuracy: 0.100265 val accura
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          lr 2.500050e-05 reg 5.180000e+05  train accuracy: 0.100265 val accura
          cy: 0.087000
          lr 2.500050e-05 reg 7.670000e+05  train accuracy: 0.100265 val accura
          cy: 0.087000
          lr 2.500050e-05 reg 1.016000e+06  train accuracy: 0.100265 val accura
          cy: 0.087000
          lr 2.500050e-05 reg 1.265000e+06  train accuracy: 0.100265 val accura
          cy: 0.087000
          lr 2.500050e-05 reg 1.514000e+06  train accuracy: 0.100265 val accura
          cy: 0.087000
          lr 2.500050e-05 reg 1.763000e+06  train accuracy: 0.100265 val accura
          cy: 0.087000
          lr 2.500050e-05 reg 2.012000e+06  train accuracy: 0.100265 val accura
          cy: 0.087000
          lr 2.500050e-05 reg 2.261000e+06  train accuracy: 0.100265 val accura
          cy: 0.087000
          lr 2.500050e-05 reg 2.510000e+06  train accuracy: 0.100265 val accura
          cy: 0.087000
          lr 2.500050e-05 reg 2.759000e+06  train accuracy: 0.100265 val accura
          cy: 0.087000
          lr 2.500050e-05 reg 3.008000e+06  train accuracy: 0.100265 val accura
          cy: 0.087000
          lr 2.500050e-05 reg 3.257000e+06  train accuracy: 0.100265 val accura
          cy: 0.087000
          lr 2.500050e-05 reg 3.506000e+06  train accuracy: 0.100265 val accura
          cy: 0.087000
          lr 2.500050e-05 reg 3.755000e+06  train accuracy: 0.100265 val accura
          cy: 0.087000
          lr 2.500050e-05 reg 4.004000e+06  train accuracy: 0.100265 val accura
          cy: 0.087000
          lr 2.500050e-05 reg 4.253000e+06  train accuracy: 0.100265 val accura
          cy: 0.087000
          lr 2.500050e-05 reg 4.502000e+06  train accuracy: 0.100265 val accura
          cy: 0.087000
          lr 2.500050e-05 reg 4.751000e+06  train accuracy: 0.100265 val accura
          cy: 0.087000
          lr 2.750045e-05 reg 2.000000e+04  train accuracy: 0.322306 val accura
          cy: 0.332000
          lr 2.750045e-05 reg 2.690000e+05  train accuracy: 0.100265 val accura
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                    cy: 0.087000
                    lr 2.750045e-05  reg 5.180000e+05   train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 2.750045e-05  reg 7.670000e+05   train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 2.750045e-05  reg 1.016000e+06   train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 2.750045e-05  reg 1.265000e+06   train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 2.750045e-05  reg 1.514000e+06   train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 2.750045e-05  reg 1.763000e+06   train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 2.750045e-05  reg 2.012000e+06   train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 2.750045e-05  reg 2.261000e+06   train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 2.750045e-05  reg 2.510000e+06   train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 2.750045e-05  reg 2.759000e+06   train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 2.750045e-05  reg 3.008000e+06   train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 2.750045e-05  reg 3.257000e+06   train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 2.750045e-05  reg 3.506000e+06   train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 2.750045e-05  reg 3.755000e+06   train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 2.750045e-05  reg 4.004000e+06   train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 2.750045e-05  reg 4.253000e+06   train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 2.750045e-05  reg 4.502000e+06   train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 2.750045e-05  reg 4.751000e+06   train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 3.000040e-05  reg 2.000000e+04   train accuracy: 0.310265 val accura
                    cy: 0.332000
                    lr 3.000040e-05  reg 2.690000e+05   train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 3.000040e-05  reg 5.180000e+05   train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 3.000040e-05  reg 7.670000e+05   train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 3.000040e-05  reg 1.016000e+06   train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 3.000040e-05  reg 1.265000e+06   train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 3.000040e-05  reg 1.514000e+06   train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 3.000040e-05  reg 1.763000e+06   train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 3.000040e-05  reg 2.012000e+06   train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 3.000040e-05  reg 2.261000e+06   train accuracy: 0.100265 val accura
                    cy: 0.087000
```

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lr 3.000040e-05 reg 2.510000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 3.000040e-05 reg 2.759000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 3.000040e-05 reg 3.008000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 3.000040e-05 reg 3.257000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 3.000040e-05 reg 3.506000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 3.000040e-05 reg 3.755000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 3.000040e-05 reg 4.004000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 3.000040e-05 reg 4.253000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 3.000040e-05 reg 4.502000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 3.000040e-05 reg 4.751000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 3.250035e-05 reg 2.000000e+04  train accuracy: 0.323449 val accura
cy: 0.317000
lr 3.250035e-05 reg 2.690000e+05  train accuracy: 0.100265 val accura
cy: 0.087000
lr 3.250035e-05 reg 5.180000e+05  train accuracy: 0.100265 val accura
cy: 0.087000
lr 3.250035e-05 reg 7.670000e+05  train accuracy: 0.100265 val accura
cy: 0.087000
lr 3.250035e-05 reg 1.016000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 3.250035e-05 reg 1.265000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 3.250035e-05 reg 1.514000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 3.250035e-05 reg 1.763000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 3.250035e-05 reg 2.012000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 3.250035e-05 reg 2.261000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 3.250035e-05 reg 2.510000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 3.250035e-05 reg 2.759000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 3.250035e-05 reg 3.008000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 3.250035e-05 reg 3.257000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 3.250035e-05 reg 3.506000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 3.250035e-05 reg 3.755000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 3.250035e-05 reg 4.004000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 3.250035e-05 reg 4.253000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 3.250035e-05 reg 4.502000e+06  train accuracy: 0.100265 val accura
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                    cy: 0.087000
                    lr 3.250035e-05 reg 4.751000e+06   train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 3.500030e-05 reg 2.000000e+04   train accuracy: 0.293082 val accura
                    cy: 0.326000
                    lr 3.500030e-05 reg 2.690000e+05   train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 3.500030e-05 reg 5.180000e+05   train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 3.500030e-05 reg 7.670000e+05   train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 3.500030e-05 reg 1.016000e+06   train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 3.500030e-05 reg 1.265000e+06   train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 3.500030e-05 reg 1.514000e+06   train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 3.500030e-05 reg 1.763000e+06   train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 3.500030e-05 reg 2.012000e+06   train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 3.500030e-05 reg 2.261000e+06   train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 3.500030e-05 reg 2.510000e+06   train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 3.500030e-05 reg 2.759000e+06   train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 3.500030e-05 reg 3.008000e+06   train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 3.500030e-05 reg 3.257000e+06   train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 3.500030e-05 reg 3.506000e+06   train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 3.500030e-05 reg 3.755000e+06   train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 3.500030e-05 reg 4.004000e+06   train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 3.500030e-05 reg 4.253000e+06   train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 3.500030e-05 reg 4.502000e+06   train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 3.500030e-05 reg 4.751000e+06   train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 3.750025e-05 reg 2.000000e+04   train accuracy: 0.288245 val accura
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                    lr 3.750025e-05 reg 2.690000e+05   train accuracy: 0.100265 val accura
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                    lr 3.750025e-05 reg 5.180000e+05   train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 3.750025e-05 reg 7.670000e+05   train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 3.750025e-05 reg 1.016000e+06   train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 3.750025e-05 reg 1.265000e+06   train accuracy: 0.100265 val accura
                    cy: 0.087000
                    lr 3.750025e-05 reg 1.514000e+06   train accuracy: 0.100265 val accura
                    cy: 0.087000
```

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lr 3.750025e-05 reg 1.763000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 3.750025e-05 reg 2.012000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 3.750025e-05 reg 2.261000e+06  train accuracy: 0.100265 val accura
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lr 3.750025e-05 reg 2.510000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 3.750025e-05 reg 2.759000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 3.750025e-05 reg 3.008000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 3.750025e-05 reg 3.257000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 3.750025e-05 reg 3.506000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 3.750025e-05 reg 3.755000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 3.750025e-05 reg 4.004000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 3.750025e-05 reg 4.253000e+06  train accuracy: 0.100265 val accura
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lr 3.750025e-05 reg 4.502000e+06  train accuracy: 0.100265 val accura
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lr 3.750025e-05 reg 4.751000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 4.000020e-05 reg 2.000000e+04  train accuracy: 0.259469 val accura
cy: 0.258000
lr 4.000020e-05 reg 2.690000e+05  train accuracy: 0.100265 val accura
cy: 0.087000
lr 4.000020e-05 reg 5.180000e+05  train accuracy: 0.100265 val accura
cy: 0.087000
lr 4.000020e-05 reg 7.670000e+05  train accuracy: 0.100265 val accura
cy: 0.087000
lr 4.000020e-05 reg 1.016000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 4.000020e-05 reg 1.265000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 4.000020e-05 reg 1.514000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 4.000020e-05 reg 1.763000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 4.000020e-05 reg 2.012000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 4.000020e-05 reg 2.261000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 4.000020e-05 reg 2.510000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 4.000020e-05 reg 2.759000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 4.000020e-05 reg 3.008000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 4.000020e-05 reg 3.257000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 4.000020e-05 reg 3.506000e+06  train accuracy: 0.100265 val accura
cy: 0.087000
lr 4.000020e-05 reg 3.755000e+06  train accuracy: 0.100265 val accura
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                     cy: 0.087000
                     lr 4.000020e-05 reg 4.004000e+06  train accuracy: 0.100265 val accura
                     cy: 0.087000
                     lr 4.000020e-05 reg 4.253000e+06  train accuracy: 0.100265 val accura
                     cy: 0.087000
                     lr 4.000020e-05 reg 4.502000e+06  train accuracy: 0.100265 val accura
                     cy: 0.087000
                     lr 4.000020e-05 reg 4.751000e+06  train accuracy: 0.100265 val accura
                     cy: 0.087000
                     lr 4.250015e-05 reg 2.000000e+04  train accuracy: 0.265082 val accura
                     cy: 0.277000
                     lr 4.250015e-05 reg 2.690000e+05  train accuracy: 0.100265 val accura
                     cy: 0.087000
                     lr 4.250015e-05 reg 5.180000e+05  train accuracy: 0.100265 val accura
                     cy: 0.087000
                     lr 4.250015e-05 reg 7.670000e+05  train accuracy: 0.100265 val accura
                     cy: 0.087000
                     lr 4.250015e-05 reg 1.016000e+06  train accuracy: 0.100265 val accura
                     cy: 0.087000
                     lr 4.250015e-05 reg 1.265000e+06  train accuracy: 0.100265 val accura
                     cy: 0.087000
                     lr 4.250015e-05 reg 1.514000e+06  train accuracy: 0.100265 val accura
                     cy: 0.087000
                     lr 4.250015e-05 reg 1.763000e+06  train accuracy: 0.100265 val accura
                     cy: 0.087000
                     lr 4.250015e-05 reg 2.012000e+06  train accuracy: 0.100265 val accura
                     cy: 0.087000
                     lr 4.250015e-05 reg 2.261000e+06  train accuracy: 0.100265 val accura
                     cy: 0.087000
                     lr 4.250015e-05 reg 2.510000e+06  train accuracy: 0.100265 val accura
                     cy: 0.087000
                     lr 4.250015e-05 reg 2.759000e+06  train accuracy: 0.100265 val accura
                     cy: 0.087000
                     lr 4.250015e-05 reg 3.008000e+06  train accuracy: 0.100265 val accura
                     cy: 0.087000
                     lr 4.250015e-05 reg 3.257000e+06  train accuracy: 0.100265 val accura
                     cy: 0.087000
                     lr 4.250015e-05 reg 3.506000e+06  train accuracy: 0.100265 val accura
                     cy: 0.087000
                     lr 4.250015e-05 reg 3.755000e+06  train accuracy: 0.100265 val accura
                     cy: 0.087000
                     lr 4.250015e-05 reg 4.004000e+06  train accuracy: 0.100265 val accura
                     cy: 0.087000
                     lr 4.250015e-05 reg 4.253000e+06  train accuracy: 0.100265 val accura
                     cy: 0.087000
                     lr 4.250015e-05 reg 4.502000e+06  train accuracy: 0.100265 val accura
                     cy: 0.087000
                     lr 4.250015e-05 reg 4.751000e+06  train accuracy: 0.100265 val accura
                     cy: 0.087000
                     lr 4.500010e-05 reg 2.000000e+04  train accuracy: 0.241735 val accura
                     cy: 0.260000
                     lr 4.500010e-05 reg 2.690000e+05  train accuracy: 0.100265 val accura
                     cy: 0.087000
                     lr 4.500010e-05 reg 5.180000e+05  train accuracy: 0.100265 val accura
                     cy: 0.087000
                     lr 4.500010e-05 reg 7.670000e+05  train accuracy: 0.100265 val accura
                     cy: 0.087000
```

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        lr 4.500010e-05 reg 1.016000e+06  train accuracy: 0.100265 val accura
        cy: 0.087000
        lr 4.500010e-05 reg 1.265000e+06  train accuracy: 0.100265 val accura
        cy: 0.087000
        lr 4.500010e-05 reg 1.514000e+06  train accuracy: 0.100265 val accura
        cy: 0.087000
        lr 4.500010e-05 reg 1.763000e+06  train accuracy: 0.100265 val accura
        cy: 0.087000
        lr 4.500010e-05 reg 2.012000e+06  train accuracy: 0.100265 val accura
        cy: 0.087000
        lr 4.500010e-05 reg 2.261000e+06  train accuracy: 0.100265 val accura
        cy: 0.087000
        lr 4.500010e-05 reg 2.510000e+06  train accuracy: 0.100265 val accura
        cy: 0.087000
        lr 4.500010e-05 reg 2.759000e+06  train accuracy: 0.100265 val accura
        cy: 0.087000
        lr 4.500010e-05 reg 3.008000e+06  train accuracy: 0.100265 val accura
        cy: 0.087000
        lr 4.500010e-05 reg 3.257000e+06  train accuracy: 0.100265 val accura
        cy: 0.087000
        lr 4.500010e-05 reg 3.506000e+06  train accuracy: 0.100265 val accura
        cy: 0.087000
        lr 4.500010e-05 reg 3.755000e+06  train accuracy: 0.100265 val accura
        cy: 0.087000
        lr 4.500010e-05 reg 4.004000e+06  train accuracy: 0.100265 val accura
        cy: 0.087000
        lr 4.500010e-05 reg 4.253000e+06  train accuracy: 0.100265 val accura
        cy: 0.087000
        lr 4.500010e-05 reg 4.502000e+06  train accuracy: 0.100265 val accura
        cy: 0.087000
        lr 4.500010e-05 reg 4.751000e+06  train accuracy: 0.100265 val accura
        cy: 0.087000
        lr 4.750005e-05 reg 2.000000e+04  train accuracy: 0.225286 val accura
        cy: 0.252000
        lr 4.750005e-05 reg 2.690000e+05  train accuracy: 0.100265 val accura
        cy: 0.087000
        lr 4.750005e-05 reg 5.180000e+05  train accuracy: 0.100265 val accura
        cy: 0.087000
        lr 4.750005e-05 reg 7.670000e+05  train accuracy: 0.100265 val accura
        cy: 0.087000
        lr 4.750005e-05 reg 1.016000e+06  train accuracy: 0.100265 val accura
        cy: 0.087000
        lr 4.750005e-05 reg 1.265000e+06  train accuracy: 0.100265 val accura
        cy: 0.087000
        lr 4.750005e-05 reg 1.514000e+06  train accuracy: 0.100265 val accura
        cy: 0.087000
        lr 4.750005e-05 reg 1.763000e+06  train accuracy: 0.100265 val accura
        cy: 0.087000
        lr 4.750005e-05 reg 2.012000e+06  train accuracy: 0.100265 val accura
        cy: 0.087000
        lr 4.750005e-05 reg 2.261000e+06  train accuracy: 0.100265 val accura
        cy: 0.087000
        lr 4.750005e-05 reg 2.510000e+06  train accuracy: 0.100265 val accura
        cy: 0.087000
        lr 4.750005e-05 reg 2.759000e+06  train accuracy: 0.100265 val accura
        cy: 0.087000
        lr 4.750005e-05 reg 3.008000e+06  train accuracy: 0.100265 val accura
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                              cy: 0.087000
                              lr 4.750005e-05 reg 3.257000e+06  train accuracy: 0.100265 val accura
                              cy: 0.087000
                              lr 4.750005e-05 reg 3.506000e+06  train accuracy: 0.100265 val accura
                              cy: 0.087000
                              lr 4.750005e-05 reg 3.755000e+06  train accuracy: 0.100265 val accura
                              cy: 0.087000
                              lr 4.750005e-05 reg 4.004000e+06  train accuracy: 0.100265 val accura
                              cy: 0.087000
                              lr 4.750005e-05 reg 4.253000e+06  train accuracy: 0.100265 val accura
                              cy: 0.087000
                              lr 4.750005e-05 reg 4.502000e+06  train accuracy: 0.100265 val accura
                              cy: 0.087000
                              lr 4.750005e-05 reg 4.751000e+06  train accuracy: 0.100265 val accura
                              cy: 0.087000
                              lr 1.000000e-09 reg 2.000000e+04 train accuracy: 0.096755 val accurac
                              y: 0.088000
                              lr 1.000000e-09 reg 2.690000e+05 train accuracy: 0.119918 val accurac
                              y: 0.098000
                              lr 1.000000e-09 reg 5.180000e+05 train accuracy: 0.085653 val accurac
                              y: 0.081000
                              lr 1.000000e-09 reg 7.670000e+05 train accuracy: 0.090796 val accurac
                              y: 0.090000
                              lr 1.000000e-09 reg 1.016000e+06 train accuracy: 0.098673 val accurac
                              y: 0.092000
                              lr 1.000000e-09 reg 1.265000e+06 train accuracy: 0.181918 val accurac
                              y: 0.163000
                              lr 1.000000e-09 reg 1.514000e+06 train accuracy: 0.331490 val accurac
                              y: 0.353000
                              lr 1.000000e-09 reg 1.763000e+06 train accuracy: 0.403327 val accurac
                              y: 0.398000
                              lr 1.000000e-09 reg 2.012000e+06 train accuracy: 0.416041 val accurac
                              y: 0.415000
                              lr 1.000000e-09 reg 2.261000e+06 train accuracy: 0.415449 val accurac
                              y: 0.417000
                              lr 1.000000e-09 reg 2.510000e+06 train accuracy: 0.413837 val accurac
                              y: 0.418000
                              lr 1.000000e-09 reg 2.759000e+06 train accuracy: 0.417020 val accurac
                              y: 0.423000
                              lr 1.000000e-09 reg 3.008000e+06 train accuracy: 0.412306 val accurac
                              y: 0.418000
                              lr 1.000000e-09 reg 3.257000e+06 train accuracy: 0.417163 val accurac
                              y: 0.416000
                              lr 1.000000e-09 reg 3.506000e+06 train accuracy: 0.417347 val accurac
                              y: 0.415000
                              lr 1.000000e-09 reg 3.755000e+06 train accuracy: 0.413531 val accurac
                              y: 0.418000
                              lr 1.000000e-09 reg 4.004000e+06 train accuracy: 0.413306 val accurac
                              y: 0.411000
                              lr 1.000000e-09 reg 4.253000e+06 train accuracy: 0.414204 val accurac
                              y: 0.419000
                              lr 1.000000e-09 reg 4.502000e+06 train accuracy: 0.416224 val accurac
                              y: 0.417000
                              lr 1.000000e-09 reg 4.751000e+06 train accuracy: 0.415939 val accurac
                              y: 0.416000
                              lr 2.500950e-06 reg 2.000000e+04 train accuracy: 0.397388 val accurac
                              y: 0.402000
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lr 2.500950e-06 reg 2.690000e+05 train accuracy: 0.300714 val accurac
y: 0.292000
lr 2.500950e-06 reg 5.180000e+05 train accuracy: 0.100265 val accurac
y: 0.087000
lr 2.500950e-06 reg 7.670000e+05 train accuracy: 0.100265 val accurac
y: 0.087000
lr 2.500950e-06 reg 1.016000e+06 train accuracy: 0.100265 val accurac
y: 0.087000
lr 2.500950e-06 reg 1.265000e+06 train accuracy: 0.100265 val accurac
y: 0.087000
lr 2.500950e-06 reg 1.514000e+06 train accuracy: 0.100265 val accurac
y: 0.087000
lr 2.500950e-06 reg 1.763000e+06 train accuracy: 0.100265 val accurac
y: 0.087000
lr 2.500950e-06 reg 2.012000e+06 train accuracy: 0.100265 val accurac
y: 0.087000
lr 2.500950e-06 reg 2.261000e+06 train accuracy: 0.100265 val accurac
y: 0.087000
lr 2.500950e-06 reg 2.510000e+06 train accuracy: 0.100265 val accurac
y: 0.087000
lr 2.500950e-06 reg 2.759000e+06 train accuracy: 0.100265 val accurac
y: 0.087000
lr 2.500950e-06 reg 3.008000e+06 train accuracy: 0.100265 val accurac
y: 0.087000
lr 2.500950e-06 reg 3.257000e+06 train accuracy: 0.100265 val accurac
y: 0.087000
lr 2.500950e-06 reg 3.506000e+06 train accuracy: 0.100265 val accurac
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lr 2.500950e-06 reg 3.755000e+06 train accuracy: 0.100265 val accurac
y: 0.087000
lr 2.500950e-06 reg 4.004000e+06 train accuracy: 0.100265 val accurac
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lr 2.500950e-06 reg 4.253000e+06 train accuracy: 0.100265 val accurac
y: 0.087000
lr 2.500950e-06 reg 4.502000e+06 train accuracy: 0.100265 val accurac
y: 0.087000
lr 2.500950e-06 reg 4.751000e+06 train accuracy: 0.100265 val accurac
y: 0.087000
lr 5.000900e-06 reg 2.000000e+04 train accuracy: 0.392592 val accurac
y: 0.380000
lr 5.000900e-06 reg 2.690000e+05 train accuracy: 0.100265 val accurac
y: 0.087000
lr 5.000900e-06 reg 5.180000e+05 train accuracy: 0.100265 val accurac
y: 0.087000
lr 5.000900e-06 reg 7.670000e+05 train accuracy: 0.100265 val accurac
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lr 5.000900e-06 reg 1.016000e+06 train accuracy: 0.100265 val accurac
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lr 5.000900e-06 reg 1.265000e+06 train accuracy: 0.100265 val accurac
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lr 5.000900e-06 reg 1.514000e+06 train accuracy: 0.100265 val accurac
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lr 5.000900e-06 reg 1.763000e+06 train accuracy: 0.100265 val accurac
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lr 5.000900e-06 reg 2.012000e+06 train accuracy: 0.100265 val accurac
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lr 5.000900e-06 reg 2.261000e+06 train accuracy: 0.100265 val accurac
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                 y: 0.087000
                 lr 5.000900e-06 reg 2.510000e+06 train accuracy: 0.100265 val accurac
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                 lr 5.000900e-06 reg 2.759000e+06 train accuracy: 0.100265 val accurac
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                 lr 5.000900e-06 reg 3.008000e+06 train accuracy: 0.100265 val accurac
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                 lr 5.000900e-06 reg 3.755000e+06 train accuracy: 0.100265 val accurac
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                 lr 5.000900e-06 reg 4.004000e+06 train accuracy: 0.100265 val accurac
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                 lr 5.000900e-06 reg 4.253000e+06 train accuracy: 0.100265 val accurac
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                 lr 5.000900e-06 reg 4.502000e+06 train accuracy: 0.100265 val accurac
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                 lr 5.000900e-06 reg 4.751000e+06 train accuracy: 0.100265 val accurac
                 y: 0.087000
                 lr 7.500850e-06 reg 2.000000e+04 train accuracy: 0.403286 val accurac
                 y: 0.398000
                 lr 7.500850e-06 reg 2.690000e+05 train accuracy: 0.100265 val accurac
                 y: 0.087000
                 lr 7.500850e-06 reg 5.180000e+05 train accuracy: 0.100265 val accurac
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                 lr 7.500850e-06 reg 7.670000e+05 train accuracy: 0.100265 val accurac
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                 lr 7.500850e-06 reg 1.016000e+06 train accuracy: 0.100265 val accurac
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                 y: 0.087000
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                 y: 0.087000
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                 lr 7.500850e-06 reg 2.510000e+06 train accuracy: 0.100265 val accurac
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                 lr 7.500850e-06 reg 4.253000e+06 train accuracy: 0.100265 val accurac
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lr 7.500850e-06 reg 4.502000e+06 train accuracy: 0.100265 val accurac
y: 0.087000
lr 7.500850e-06 reg 4.751000e+06 train accuracy: 0.100265 val accurac
y: 0.087000
lr 1.000080e-05 reg 2.000000e+04 train accuracy: 0.380245 val accurac
y: 0.383000
lr 1.000080e-05 reg 2.690000e+05 train accuracy: 0.100265 val accurac
y: 0.087000
lr 1.000080e-05 reg 5.180000e+05 train accuracy: 0.100265 val accurac
y: 0.087000
lr 1.000080e-05 reg 7.670000e+05 train accuracy: 0.100265 val accurac
y: 0.087000
lr 1.000080e-05 reg 1.016000e+06 train accuracy: 0.100265 val accurac
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lr 1.000080e-05 reg 1.265000e+06 train accuracy: 0.100265 val accurac
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lr 1.000080e-05 reg 1.514000e+06 train accuracy: 0.100265 val accurac
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lr 1.000080e-05 reg 1.763000e+06 train accuracy: 0.100265 val accurac
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lr 1.000080e-05 reg 3.008000e+06 train accuracy: 0.100265 val accurac
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lr 1.000080e-05 reg 4.751000e+06 train accuracy: 0.100265 val accurac
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lr 1.250075e-05 reg 2.000000e+04 train accuracy: 0.394245 val accurac
y: 0.406000
lr 1.250075e-05 reg 2.690000e+05 train accuracy: 0.100265 val accurac
y: 0.087000
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lr 1.250075e-05 reg 7.670000e+05 train accuracy: 0.100265 val accurac
y: 0.087000
lr 1.250075e-05 reg 1.016000e+06 train accuracy: 0.100265 val accurac
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lr 1.250075e-05 reg 1.265000e+06 train accuracy: 0.100265 val accurac
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lr 1.250075e-05 reg 1.514000e+06 train accuracy: 0.100265 val accurac

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                y: 0.087000
                lr 1.250075e-05 reg 1.763000e+06 train accuracy: 0.100265 val accurac
                y: 0.087000
                lr 1.250075e-05 reg 2.012000e+06 train accuracy: 0.100265 val accurac
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                lr 1.250075e-05 reg 2.261000e+06 train accuracy: 0.100265 val accurac
                y: 0.087000
                lr 1.250075e-05 reg 2.510000e+06 train accuracy: 0.100265 val accurac
                y: 0.087000
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                y: 0.087000
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                y: 0.087000
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                y: 0.087000
                lr 1.250075e-05 reg 3.755000e+06 train accuracy: 0.100265 val accurac
                y: 0.087000
                lr 1.250075e-05 reg 4.004000e+06 train accuracy: 0.100265 val accurac
                y: 0.087000
                lr 1.250075e-05 reg 4.253000e+06 train accuracy: 0.100265 val accurac
                y: 0.087000
                lr 1.250075e-05 reg 4.502000e+06 train accuracy: 0.100265 val accurac
                y: 0.087000
                lr 1.250075e-05 reg 4.751000e+06 train accuracy: 0.100265 val accurac
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                lr 1.500070e-05 reg 2.690000e+05 train accuracy: 0.100265 val accurac
                y: 0.087000
                lr 1.500070e-05 reg 5.180000e+05 train accuracy: 0.100265 val accurac
                y: 0.087000
                lr 1.500070e-05 reg 7.670000e+05 train accuracy: 0.100265 val accurac
                y: 0.087000
                lr 1.500070e-05 reg 1.016000e+06 train accuracy: 0.100265 val accurac
                y: 0.087000
                lr 1.500070e-05 reg 1.265000e+06 train accuracy: 0.100265 val accurac
                y: 0.087000
                lr 1.500070e-05 reg 1.514000e+06 train accuracy: 0.100265 val accurac
                y: 0.087000
                lr 1.500070e-05 reg 1.763000e+06 train accuracy: 0.100265 val accurac
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                lr 1.500070e-05 reg 2.510000e+06 train accuracy: 0.100265 val accurac
                y: 0.087000
                lr 1.500070e-05 reg 2.759000e+06 train accuracy: 0.100265 val accurac
                y: 0.087000
                lr 1.500070e-05 reg 3.008000e+06 train accuracy: 0.100265 val accurac
                y: 0.087000
                lr 1.500070e-05 reg 3.257000e+06 train accuracy: 0.100265 val accurac
                y: 0.087000
                lr 1.500070e-05 reg 3.506000e+06 train accuracy: 0.100265 val accurac
                y: 0.087000
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lr 1.500070e-05 reg 3.755000e+06 train accuracy: 0.100265 val accurac
y: 0.087000
lr 1.500070e-05 reg 4.004000e+06 train accuracy: 0.100265 val accurac
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lr 1.500070e-05 reg 4.253000e+06 train accuracy: 0.100265 val accurac
y: 0.087000
lr 1.500070e-05 reg 4.502000e+06 train accuracy: 0.100265 val accurac
y: 0.087000
lr 1.500070e-05 reg 4.751000e+06 train accuracy: 0.100265 val accurac
y: 0.087000
lr 1.750065e-05 reg 2.000000e+04 train accuracy: 0.342980 val accurac
y: 0.357000
lr 1.750065e-05 reg 2.690000e+05 train accuracy: 0.100265 val accurac
y: 0.087000
lr 1.750065e-05 reg 5.180000e+05 train accuracy: 0.100265 val accurac
y: 0.087000
lr 1.750065e-05 reg 7.670000e+05 train accuracy: 0.100265 val accurac
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lr 1.750065e-05 reg 1.514000e+06 train accuracy: 0.100265 val accurac
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lr 1.750065e-05 reg 1.763000e+06 train accuracy: 0.100265 val accurac
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lr 1.750065e-05 reg 2.510000e+06 train accuracy: 0.100265 val accurac
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lr 1.750065e-05 reg 2.759000e+06 train accuracy: 0.100265 val accurac
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lr 1.750065e-05 reg 3.257000e+06 train accuracy: 0.100265 val accurac
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lr 1.750065e-05 reg 3.506000e+06 train accuracy: 0.100265 val accurac
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lr 1.750065e-05 reg 4.004000e+06 train accuracy: 0.100265 val accurac
y: 0.087000
lr 1.750065e-05 reg 4.253000e+06 train accuracy: 0.100265 val accurac
y: 0.087000
lr 1.750065e-05 reg 4.502000e+06 train accuracy: 0.100265 val accurac
y: 0.087000
lr 1.750065e-05 reg 4.751000e+06 train accuracy: 0.100265 val accurac
y: 0.087000
lr 2.000060e-05 reg 2.000000e+04 train accuracy: 0.356714 val accurac
y: 0.371000
lr 2.000060e-05 reg 2.690000e+05 train accuracy: 0.100265 val accurac
y: 0.087000
lr 2.000060e-05 reg 5.180000e+05 train accuracy: 0.100265 val accurac
y: 0.087000
lr 2.000060e-05 reg 7.670000e+05 train accuracy: 0.100265 val accurac
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y: 0.087000
lr 2.000060e-05 reg 1.016000e+06 train accuracy: 0.100265 val accurac
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lr 2.000060e-05 reg 1.265000e+06 train accuracy: 0.100265 val accurac
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lr 2.000060e-05 reg 4.751000e+06 train accuracy: 0.100265 val accurac
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lr 2.250055e-05 reg 2.000000e+04 train accuracy: 0.334122 val accurac
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lr 2.250055e-05 reg 2.690000e+05 train accuracy: 0.100265 val accurac
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         lr 2.250055e-05 reg 3.008000e+06 train accuracy: 0.100265 val accurac
         y: 0.087000
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         y: 0.087000
         lr 2.250055e-05 reg 4.751000e+06 train accuracy: 0.100265 val accurac
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         lr 2.500050e-05 reg 5.180000e+05 train accuracy: 0.100265 val accurac
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         lr 2.500050e-05 reg 7.670000e+05 train accuracy: 0.100265 val accurac
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         lr 2.500050e-05 reg 1.016000e+06 train accuracy: 0.100265 val accurac
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         y: 0.087000
         lr 2.500050e-05 reg 4.751000e+06 train accuracy: 0.100265 val accurac
         y: 0.087000
         lr 2.750045e-05 reg 2.000000e+04 train accuracy: 0.322306 val accurac
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y: 0.332000
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y: 0.087000
lr 2.750045e-05 reg 5.180000e+05 train accuracy: 0.100265 val accurac
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lr 2.750045e-05 reg 7.670000e+05 train accuracy: 0.100265 val accurac
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lr 2.750045e-05 reg 1.016000e+06 train accuracy: 0.100265 val accurac
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lr 2.750045e-05 reg 1.763000e+06 train accuracy: 0.100265 val accurac
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lr 3.000040e-05 reg 2.000000e+04 train accuracy: 0.310265 val accurac
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lr 3.000040e-05 reg 2.690000e+05 train accuracy: 0.100265 val accurac
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lr 3.000040e-05 reg 7.670000e+05 train accuracy: 0.100265 val accurac
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lr 3.000040e-05 reg 1.265000e+06 train accuracy: 0.100265 val accurac
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lr 3.000040e-05 reg 1.514000e+06 train accuracy: 0.100265 val accurac
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lr 3.000040e-05 reg 1.763000e+06 train accuracy: 0.100265 val accurac
y: 0.087000
lr 3.000040e-05 reg 2.012000e+06 train accuracy: 0.100265 val accurac
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lr 3.000040e-05 reg 2.261000e+06 train accuracy: 0.100265 val accurac
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lr 3.250035e-05 reg 5.180000e+05 train accuracy: 0.100265 val accurac
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lr 3.250035e-05 reg 7.670000e+05 train accuracy: 0.100265 val accurac
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lr 3.250035e-05 reg 1.016000e+06 train accuracy: 0.100265 val accurac
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lr 3.250035e-05 reg 1.265000e+06 train accuracy: 0.100265 val accurac
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lr 3.250035e-05 reg 1.514000e+06 train accuracy: 0.100265 val accurac
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lr 3.250035e-05 reg 1.763000e+06 train accuracy: 0.100265 val accurac
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lr 3.250035e-05 reg 2.012000e+06 train accuracy: 0.100265 val accurac
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lr 3.250035e-05 reg 2.510000e+06 train accuracy: 0.100265 val accurac
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lr 3.250035e-05 reg 2.759000e+06 train accuracy: 0.100265 val accurac
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lr 3.250035e-05 reg 3.008000e+06 train accuracy: 0.100265 val accurac
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lr 3.250035e-05 reg 3.257000e+06 train accuracy: 0.100265 val accurac
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lr 3.250035e-05 reg 3.755000e+06 train accuracy: 0.100265 val accurac
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y: 0.087000
lr 3.250035e-05 reg 4.502000e+06 train accuracy: 0.100265 val accurac
y: 0.087000
lr 3.250035e-05 reg 4.751000e+06 train accuracy: 0.100265 val accurac
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lr 3.500030e-05 reg 2.690000e+05 train accuracy: 0.100265 val accurac
y: 0.087000
lr 3.500030e-05 reg 5.180000e+05 train accuracy: 0.100265 val accurac
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lr 3.500030e-05 reg 7.670000e+05 train accuracy: 0.100265 val accurac
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lr 3.500030e-05 reg 1.016000e+06 train accuracy: 0.100265 val accurac
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lr 3.500030e-05 reg 1.265000e+06 train accuracy: 0.100265 val accurac
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lr 3.500030e-05 reg 1.514000e+06 train accuracy: 0.100265 val accurac
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lr 3.500030e-05 reg 4.502000e+06 train accuracy: 0.100265 val accurac
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lr 3.500030e-05 reg 4.751000e+06 train accuracy: 0.100265 val accurac
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y: 0.087000
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lr 3.750025e-05 reg 1.514000e+06 train accuracy: 0.100265 val accurac
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lr 4.000020e-05 reg 2.690000e+05 train accuracy: 0.100265 val accurac
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                    y: 0.087000
                    lr 4.000020e-05 reg 3.755000e+06 train accuracy: 0.100265 val accurac
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                    lr 4.500010e-05 reg 2.690000e+05 train accuracy: 0.100265 val accurac
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                    lr 4.500010e-05 reg 5.180000e+05 train accuracy: 0.100265 val accurac
                    y: 0.087000
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lr 4.500010e-05 reg 7.670000e+05 train accuracy: 0.100265 val accurac
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y: 0.087000
lr 4.500010e-05 reg 3.506000e+06 train accuracy: 0.100265 val accurac
y: 0.087000
lr 4.500010e-05 reg 3.755000e+06 train accuracy: 0.100265 val accurac
y: 0.087000
lr 4.500010e-05 reg 4.004000e+06 train accuracy: 0.100265 val accurac
y: 0.087000
lr 4.500010e-05 reg 4.253000e+06 train accuracy: 0.100265 val accurac
y: 0.087000
lr 4.500010e-05 reg 4.502000e+06 train accuracy: 0.100265 val accurac
y: 0.087000
lr 4.500010e-05 reg 4.751000e+06 train accuracy: 0.100265 val accurac
y: 0.087000
lr 4.750005e-05 reg 2.000000e+04 train accuracy: 0.225286 val accurac
y: 0.252000
lr 4.750005e-05 reg 2.690000e+05 train accuracy: 0.100265 val accurac
y: 0.087000
lr 4.750005e-05 reg 5.180000e+05 train accuracy: 0.100265 val accurac
y: 0.087000
lr 4.750005e-05 reg 7.670000e+05 train accuracy: 0.100265 val accurac
y: 0.087000
lr 4.750005e-05 reg 1.016000e+06 train accuracy: 0.100265 val accurac
y: 0.087000
lr 4.750005e-05 reg 1.265000e+06 train accuracy: 0.100265 val accurac
y: 0.087000
lr 4.750005e-05 reg 1.514000e+06 train accuracy: 0.100265 val accurac
y: 0.087000
lr 4.750005e-05 reg 1.763000e+06 train accuracy: 0.100265 val accurac
y: 0.087000
lr 4.750005e-05 reg 2.012000e+06 train accuracy: 0.100265 val accurac
y: 0.087000
lr 4.750005e-05 reg 2.261000e+06 train accuracy: 0.100265 val accurac
y: 0.087000
lr 4.750005e-05 reg 2.510000e+06 train accuracy: 0.100265 val accurac
y: 0.087000
lr 4.750005e-05 reg 2.759000e+06 train accuracy: 0.100265 val accurac
```

```
        y: 0.087000
        lr 4.750005e-05 reg 3.008000e+06 train accuracy: 0.100265 val accurac
        y: 0.087000
        lr 4.750005e-05 reg 3.257000e+06 train accuracy: 0.100265 val accurac
        y: 0.087000
        lr 4.750005e-05 reg 3.506000e+06 train accuracy: 0.100265 val accurac
        y: 0.087000
        lr 4.750005e-05 reg 3.755000e+06 train accuracy: 0.100265 val accurac
        y: 0.087000
        lr 4.750005e-05 reg 4.004000e+06 train accuracy: 0.100265 val accurac
        y: 0.087000
        lr 4.750005e-05 reg 4.253000e+06 train accuracy: 0.100265 val accurac
        y: 0.087000
        lr 4.750005e-05 reg 4.502000e+06 train accuracy: 0.100265 val accurac
        y: 0.087000
        lr 4.750005e-05 reg 4.751000e+06 train accuracy: 0.100265 val accurac
        y: 0.087000
        best validation accuracy achieved during cross-validation: 0.423000
```

In [10]:
```python
# Evaluate your trained SVM on the test set
y_test_pred = best_svm.predict(X_test_feats)
test_accuracy = np.mean(y_test == y_test_pred)
print(test_accuracy)
```

```
0.418
```

```
In [11]:  # An important way to gain intuition about how an algorithm works is
           to
          # visualize the mistakes that it makes. In this visualization, we sho
          w examples
          # of images that are misclassified by our current system. The first c
          olumn
          # shows images that our system labeled as "plane" but whose true labe
          l is
          # something other than "plane".

          examples_per_class = 8
          classes = ['plane', 'car', 'bird', 'cat', 'deer', 'dog', 'frog', 'hor
          se', 'ship', 'truck']
          for cls, cls_name in enumerate(classes):
              idxs = np.where((y_test != cls) & (y_test_pred == cls))[0]
              idxs = np.random.choice(idxs, examples_per_class, replace=False)
              for i, idx in enumerate(idxs):
                  plt.subplot(examples_per_class, len(classes), i * len(classes
          ) + cls + 1)
                  plt.imshow(X_test[idx].astype('uint8'))
                  plt.axis('off')
                  if i == 0:
                      plt.title(cls_name)
          plt.show()
```
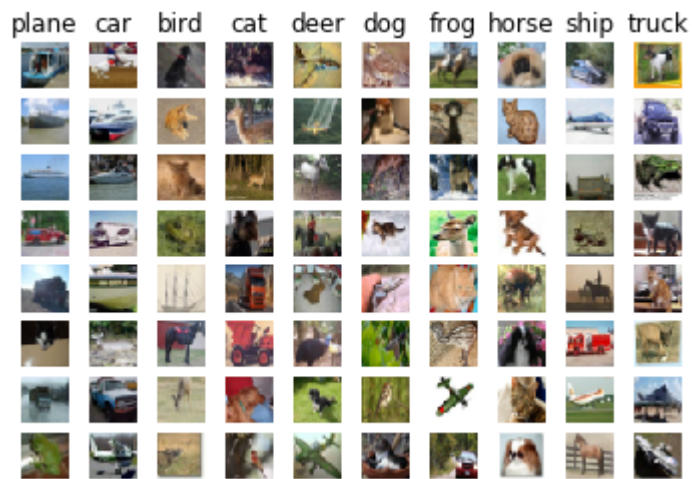

Inline question 1:

Describe the misclassification results that you see. Do they make sense?

They kind of make sense. For example, misclassificatoins in plane category were most probably becuase there is lot of sky and bluish tinge in those images. Similary, in car category, it put some ships and trucks, which look a lot like a car in some angles. So,yes. It does make sense.

Neural Network on image features

Earlier in this assigment we saw that training a two-layer neural network on raw pixels achieved better classification performance than linear classifiers on raw pixels. In this notebook we have seen that linear classifiers on image features outperform linear classifiers on raw pixels.

For completeness, we should also try training a neural network on image features. This approach should outperform all previous approaches: you should easily be able to achieve over 55% classification accuracy on the test set; our best model achieves about 60% classification accuracy.

```
In [12]:  # Preprocessing: Remove the bias dimension
          # Make sure to run this cell only ONCE
          print(X_train_feats.shape)
          X_train_feats = X_train_feats[:, :-1]
          X_val_feats = X_val_feats[:, :-1]
          X_test_feats = X_test_feats[:, :-1]

          print(X_train_feats.shape)
```

```
(49000, 155)
(49000, 154)
```

```
In [26]: from cs682.classifiers.neural_net import TwoLayerNet

# input_dim = X_train_feats.shape[1]
# hidden_dim = 500
# num_classes = 10

# net = TwoLayerNet(input_dim, hidden_dim, num_classes)
# best_net = None

################################################################################
###########
# TODO: Train a two-layer neural network on image features. You may w
ant to      #
# cross-validate various parameters as in previous sections. Store yo
ur best    #
# model in the best_net variable.
#
################################################################################
###########
best_net = None # store the best model into this
input_size = X_train_feats.shape[1]
learning_rates = [1e-1, 9e-1]
regularization_strengths = [1e-2, 1e-1]
hiddenSizes = range(500,501)
num_classes = 10
results = {}
best_val = -1
best_lr = -1
best_reg = -1
best_hidden_size = -1
inner_iterations = 3000
batch_size = 200
learning_rate_decay=0.95

num_iters = 10
for it in range(num_iters):
    for jt in range(num_iters):
        for kt in range(len(hiddenSizes)):
            learning_rate = learning_rates[0] + it * ((learning_rates
[1] - learning_rates[0]) / num_iters)
            reg = regularization_strengths[0] + jt * ((regularization
_strengths[1] - regularization_strengths[0])/ num_iters)
            hidden_size = hiddenSizes[kt]

            net = TwoLayerNet(input_size, hidden_size, num_classes)
            # Train the network
            stats = net.train(X_train_feats, y_train, X_val_feats, y_
val,
                    learning_rate, learning_rate_decay,
                    reg, inner_iterations, batch_size,verbose=Fal
se)

            y_train_pred = net.predict(X_train_feats)
            y_val_pred = net.predict(X_val_feats)
            training_accuracy = np.mean(y_train == y_train_pred)
            validation_accuracy = np.mean(y_val == y_val_pred)
```

```python
                results[(learning_rate, reg, hidden_size)] = (training_ac
curacy, validation_accuracy)
            print('lr %e reg %e hidden %f train accuracy: %f val accu
racy: %f' % (
                        learning_rate, reg, hidden_size, training_acc
uracy, validation_accuracy))
            if validation_accuracy > best_val:
                best_val = validation_accuracy
                best_net = net
                best_lr = learning_rate
                best_reg = reg
                best_hidden_size = hidden_size

print('best validation accuracy achieved during cross-validation: lr
%e reg %e hidden %f val accuracy: %f, ' % (learning_rate, reg, hidden
_size, best_val))


################################################################################
##########
#                          END OF YOUR CODE
#
################################################################################
##########
```

lr 1.000000e-01 reg 1.000000e-02 hidden 500.000000 train accuracy: 0.523612 val accuracy: 0.517000
lr 1.000000e-01 reg 1.900000e-02 hidden 500.000000 train accuracy: 0.504714 val accuracy: 0.503000
lr 1.000000e-01 reg 2.800000e-02 hidden 500.000000 train accuracy: 0.491878 val accuracy: 0.489000
lr 1.000000e-01 reg 3.700000e-02 hidden 500.000000 train accuracy: 0.468082 val accuracy: 0.466000
lr 1.000000e-01 reg 4.600000e-02 hidden 500.000000 train accuracy: 0.451755 val accuracy: 0.454000
lr 1.000000e-01 reg 5.500000e-02 hidden 500.000000 train accuracy: 0.435306 val accuracy: 0.423000
lr 1.000000e-01 reg 6.400000e-02 hidden 500.000000 train accuracy: 0.416347 val accuracy: 0.410000
lr 1.000000e-01 reg 7.300000e-02 hidden 500.000000 train accuracy: 0.389245 val accuracy: 0.390000
lr 1.000000e-01 reg 8.200000e-02 hidden 500.000000 train accuracy: 0.364878 val accuracy: 0.370000
lr 1.000000e-01 reg 9.100000e-02 hidden 500.000000 train accuracy: 0.346286 val accuracy: 0.346000
lr 1.800000e-01 reg 1.000000e-02 hidden 500.000000 train accuracy: 0.527898 val accuracy: 0.507000
lr 1.800000e-01 reg 1.900000e-02 hidden 500.000000 train accuracy: 0.510082 val accuracy: 0.510000
lr 1.800000e-01 reg 2.800000e-02 hidden 500.000000 train accuracy: 0.490653 val accuracy: 0.497000
lr 1.800000e-01 reg 3.700000e-02 hidden 500.000000 train accuracy: 0.466449 val accuracy: 0.456000
lr 1.800000e-01 reg 4.600000e-02 hidden 500.000000 train accuracy: 0.449571 val accuracy: 0.451000
lr 1.800000e-01 reg 5.500000e-02 hidden 500.000000 train accuracy: 0.433388 val accuracy: 0.435000
lr 1.800000e-01 reg 6.400000e-02 hidden 500.000000 train accuracy: 0.413633 val accuracy: 0.413000
lr 1.800000e-01 reg 7.300000e-02 hidden 500.000000 train accuracy: 0.402490 val accuracy: 0.396000
lr 1.800000e-01 reg 8.200000e-02 hidden 500.000000 train accuracy: 0.371347 val accuracy: 0.355000
lr 1.800000e-01 reg 9.100000e-02 hidden 500.000000 train accuracy: 0.365612 val accuracy: 0.344000
lr 2.600000e-01 reg 1.000000e-02 hidden 500.000000 train accuracy: 0.532612 val accuracy: 0.522000
lr 2.600000e-01 reg 1.900000e-02 hidden 500.000000 train accuracy: 0.497429 val accuracy: 0.497000
lr 2.600000e-01 reg 2.800000e-02 hidden 500.000000 train accuracy: 0.490204 val accuracy: 0.474000
lr 2.600000e-01 reg 3.700000e-02 hidden 500.000000 train accuracy: 0.460694 val accuracy: 0.456000
lr 2.600000e-01 reg 4.600000e-02 hidden 500.000000 train accuracy: 0.446694 val accuracy: 0.458000
lr 2.600000e-01 reg 5.500000e-02 hidden 500.000000 train accuracy: 0.422469 val accuracy: 0.419000
lr 2.600000e-01 reg 6.400000e-02 hidden 500.000000 train accuracy: 0.409878 val accuracy: 0.408000
lr 2.600000e-01 reg 7.300000e-02 hidden 500.000000 train accuracy: 0.405327 val accuracy: 0.424000
lr 2.600000e-01 reg 8.200000e-02 hidden 500.000000 train accuracy: 0.

369816 val accuracy: 0.353000
lr 2.600000e-01 reg 9.100000e-02 hidden 500.000000 train accuracy: 0.
361673 val accuracy: 0.361000
lr 3.400000e-01 reg 1.000000e-02 hidden 500.000000 train accuracy: 0.
528469 val accuracy: 0.522000
lr 3.400000e-01 reg 1.900000e-02 hidden 500.000000 train accuracy: 0.
503367 val accuracy: 0.484000
lr 3.400000e-01 reg 2.800000e-02 hidden 500.000000 train accuracy: 0.
491898 val accuracy: 0.493000
lr 3.400000e-01 reg 3.700000e-02 hidden 500.000000 train accuracy: 0.
455163 val accuracy: 0.421000
lr 3.400000e-01 reg 4.600000e-02 hidden 500.000000 train accuracy: 0.
447102 val accuracy: 0.450000
lr 3.400000e-01 reg 5.500000e-02 hidden 500.000000 train accuracy: 0.
409980 val accuracy: 0.407000
lr 3.400000e-01 reg 6.400000e-02 hidden 500.000000 train accuracy: 0.
413041 val accuracy: 0.391000
lr 3.400000e-01 reg 7.300000e-02 hidden 500.000000 train accuracy: 0.
392122 val accuracy: 0.372000
lr 3.400000e-01 reg 8.200000e-02 hidden 500.000000 train accuracy: 0.
367980 val accuracy: 0.354000
lr 3.400000e-01 reg 9.100000e-02 hidden 500.000000 train accuracy: 0.
366531 val accuracy: 0.342000
lr 4.200000e-01 reg 1.000000e-02 hidden 500.000000 train accuracy: 0.
528367 val accuracy: 0.521000
lr 4.200000e-01 reg 1.900000e-02 hidden 500.000000 train accuracy: 0.
502755 val accuracy: 0.501000
lr 4.200000e-01 reg 2.800000e-02 hidden 500.000000 train accuracy: 0.
484735 val accuracy: 0.475000
lr 4.200000e-01 reg 3.700000e-02 hidden 500.000000 train accuracy: 0.
457939 val accuracy: 0.451000
lr 4.200000e-01 reg 4.600000e-02 hidden 500.000000 train accuracy: 0.
432306 val accuracy: 0.429000
lr 4.200000e-01 reg 5.500000e-02 hidden 500.000000 train accuracy: 0.
411878 val accuracy: 0.405000
lr 4.200000e-01 reg 6.400000e-02 hidden 500.000000 train accuracy: 0.
398673 val accuracy: 0.377000
lr 4.200000e-01 reg 7.300000e-02 hidden 500.000000 train accuracy: 0.
382571 val accuracy: 0.370000
lr 4.200000e-01 reg 8.200000e-02 hidden 500.000000 train accuracy: 0.
362898 val accuracy: 0.347000
lr 4.200000e-01 reg 9.100000e-02 hidden 500.000000 train accuracy: 0.
273204 val accuracy: 0.247000
lr 5.000000e-01 reg 1.000000e-02 hidden 500.000000 train accuracy: 0.
526612 val accuracy: 0.521000
lr 5.000000e-01 reg 1.900000e-02 hidden 500.000000 train accuracy: 0.
495714 val accuracy: 0.491000
lr 5.000000e-01 reg 2.800000e-02 hidden 500.000000 train accuracy: 0.
481082 val accuracy: 0.484000
lr 5.000000e-01 reg 3.700000e-02 hidden 500.000000 train accuracy: 0.
447898 val accuracy: 0.429000
lr 5.000000e-01 reg 4.600000e-02 hidden 500.000000 train accuracy: 0.
426143 val accuracy: 0.446000
lr 5.000000e-01 reg 5.500000e-02 hidden 500.000000 train accuracy: 0.
413286 val accuracy: 0.415000
lr 5.000000e-01 reg 6.400000e-02 hidden 500.000000 train accuracy: 0.
391000 val accuracy: 0.384000

lr 5.000000e-01 reg 7.300000e-02 hidden 500.000000 train accuracy: 0.
400184 val accuracy: 0.398000
lr 5.000000e-01 reg 8.200000e-02 hidden 500.000000 train accuracy: 0.
374673 val accuracy: 0.369000
lr 5.000000e-01 reg 9.100000e-02 hidden 500.000000 train accuracy: 0.
339122 val accuracy: 0.320000
lr 5.800000e-01 reg 1.000000e-02 hidden 500.000000 train accuracy: 0.
526265 val accuracy: 0.534000
lr 5.800000e-01 reg 1.900000e-02 hidden 500.000000 train accuracy: 0.
491653 val accuracy: 0.488000
lr 5.800000e-01 reg 2.800000e-02 hidden 500.000000 train accuracy: 0.
465327 val accuracy: 0.464000
lr 5.800000e-01 reg 3.700000e-02 hidden 500.000000 train accuracy: 0.
458714 val accuracy: 0.457000
lr 5.800000e-01 reg 4.600000e-02 hidden 500.000000 train accuracy: 0.
419102 val accuracy: 0.409000
lr 5.800000e-01 reg 5.500000e-02 hidden 500.000000 train accuracy: 0.
400122 val accuracy: 0.400000
lr 5.800000e-01 reg 6.400000e-02 hidden 500.000000 train accuracy: 0.
394898 val accuracy: 0.371000
lr 5.800000e-01 reg 7.300000e-02 hidden 500.000000 train accuracy: 0.
377776 val accuracy: 0.369000
lr 5.800000e-01 reg 8.200000e-02 hidden 500.000000 train accuracy: 0.
347612 val accuracy: 0.349000
lr 5.800000e-01 reg 9.100000e-02 hidden 500.000000 train accuracy: 0.
347000 val accuracy: 0.339000
lr 6.600000e-01 reg 1.000000e-02 hidden 500.000000 train accuracy: 0.
518490 val accuracy: 0.504000
lr 6.600000e-01 reg 1.900000e-02 hidden 500.000000 train accuracy: 0.
487143 val accuracy: 0.507000
lr 6.600000e-01 reg 2.800000e-02 hidden 500.000000 train accuracy: 0.
467694 val accuracy: 0.462000
lr 6.600000e-01 reg 3.700000e-02 hidden 500.000000 train accuracy: 0.
439918 val accuracy: 0.452000
lr 6.600000e-01 reg 4.600000e-02 hidden 500.000000 train accuracy: 0.
431939 val accuracy: 0.413000
lr 6.600000e-01 reg 5.500000e-02 hidden 500.000000 train accuracy: 0.
404469 val accuracy: 0.413000
lr 6.600000e-01 reg 6.400000e-02 hidden 500.000000 train accuracy: 0.
403755 val accuracy: 0.413000
lr 6.600000e-01 reg 7.300000e-02 hidden 500.000000 train accuracy: 0.
312184 val accuracy: 0.315000
lr 6.600000e-01 reg 8.200000e-02 hidden 500.000000 train accuracy: 0.
359612 val accuracy: 0.341000
lr 6.600000e-01 reg 9.100000e-02 hidden 500.000000 train accuracy: 0.
327694 val accuracy: 0.296000
lr 7.400000e-01 reg 1.000000e-02 hidden 500.000000 train accuracy: 0.
513102 val accuracy: 0.502000
lr 7.400000e-01 reg 1.900000e-02 hidden 500.000000 train accuracy: 0.
473449 val accuracy: 0.475000
lr 7.400000e-01 reg 2.800000e-02 hidden 500.000000 train accuracy: 0.
481469 val accuracy: 0.472000
lr 7.400000e-01 reg 3.700000e-02 hidden 500.000000 train accuracy: 0.
443571 val accuracy: 0.409000
lr 7.400000e-01 reg 4.600000e-02 hidden 500.000000 train accuracy: 0.
426714 val accuracy: 0.436000
lr 7.400000e-01 reg 5.500000e-02 hidden 500.000000 train accuracy: 0.

```
383694 val accuracy: 0.386000
lr 7.400000e-01 reg 6.400000e-02 hidden 500.000000 train accuracy: 0.
386776 val accuracy: 0.390000
lr 7.400000e-01 reg 7.300000e-02 hidden 500.000000 train accuracy: 0.
368551 val accuracy: 0.353000
lr 7.400000e-01 reg 8.200000e-02 hidden 500.000000 train accuracy: 0.
325898 val accuracy: 0.307000
lr 7.400000e-01 reg 9.100000e-02 hidden 500.000000 train accuracy: 0.
305388 val accuracy: 0.307000
lr 8.200000e-01 reg 1.000000e-02 hidden 500.000000 train accuracy: 0.
518673 val accuracy: 0.500000
lr 8.200000e-01 reg 1.900000e-02 hidden 500.000000 train accuracy: 0.
473633 val accuracy: 0.489000
lr 8.200000e-01 reg 2.800000e-02 hidden 500.000000 train accuracy: 0.
459327 val accuracy: 0.448000
lr 8.200000e-01 reg 3.700000e-02 hidden 500.000000 train accuracy: 0.
446082 val accuracy: 0.446000
lr 8.200000e-01 reg 4.600000e-02 hidden 500.000000 train accuracy: 0.
436224 val accuracy: 0.436000
lr 8.200000e-01 reg 5.500000e-02 hidden 500.000000 train accuracy: 0.
403837 val accuracy: 0.391000
lr 8.200000e-01 reg 6.400000e-02 hidden 500.000000 train accuracy: 0.
387408 val accuracy: 0.368000
lr 8.200000e-01 reg 7.300000e-02 hidden 500.000000 train accuracy: 0.
361102 val accuracy: 0.374000
lr 8.200000e-01 reg 8.200000e-02 hidden 500.000000 train accuracy: 0.
359122 val accuracy: 0.343000
lr 8.200000e-01 reg 9.100000e-02 hidden 500.000000 train accuracy: 0.
331408 val accuracy: 0.314000
best validation accuracy achieved during cross-validation: lr 8.20000
0e-01 reg 9.100000e-02 hidden 500.000000 val accuracy: 0.534000,
```

In [27]:
```python
# Run your best neural net classifier on the test set. You should be
 able
# to get more than 55% accuracy.

test_acc = (best_net.predict(X_test_feats) == y_test).mean()
print(test_acc)
```

```
0.514
```

In [ ]: