

features

December 12, 2024

```
[1]: # This mounts your Google Drive to the Colab VM.
from google.colab import drive
drive.mount('/content/drive')

# TODO: Enter the foldername in your Drive where you have saved the unzipped
# assignment folder, e.g. 'cs6353/assignments/assignment2/'
FOLDERNAME = 'cs6353/assignments/assignment2/'
assert FOLDERNAME is not None, "[!] Enter the foldername."

# Now that we've mounted your Drive, this ensures that
# the Python interpreter of the Colab VM can load
# python files from within it.
import sys
sys.path.append('/content/drive/My Drive/{}'.format(FOLDERNAME))

# This downloads the CIFAR-10 dataset to your Drive
# if it doesn't already exist.
%cd /content/drive/My\ Drive/$FOLDERNAME/datasets/
!bash get_datasets.sh
%cd /content/drive/My\ Drive/$FOLDERNAME

# Install requirements from colab_requirements.txt
# TODO: Please change your path below to the colab_requirements.txt file
! python -m pip install -r /content/drive/My\ Drive/$FOLDERNAME/
↳ colab_requirements.txt
```

```
Mounted at /content/drive
/content/drive/My Drive/cs6353/assignments/assignment2/cs6353/datasets
--2024-12-06 20:32:12-- http://www.cs.toronto.edu/~kriz/cifar-10-python.tar.gz
Resolving www.cs.toronto.edu (www.cs.toronto.edu)... 128.100.3.30
Connecting to www.cs.toronto.edu (www.cs.toronto.edu)|128.100.3.30|:80...
connected.
HTTP request sent, awaiting response... 200 OK
Length: 170498071 (163M) [application/x-gzip]
Saving to: 'cifar-10-python.tar.gz'
```

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cifar-10-python.tar 100%[=====>] 162.60M 39.5MB/s in 4.5s
```

2024-12-06 20:32:16 (36.2 MB/s) - 'cifar-10-python.tar.gz' saved
[170498071/170498071]

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cifar-10-batches-py/  
cifar-10-batches-py/data_batch_4  
cifar-10-batches-py/readme.html  
cifar-10-batches-py/test_batch  
cifar-10-batches-py/data_batch_3  
cifar-10-batches-py/batches.meta  
cifar-10-batches-py/data_batch_2  
cifar-10-batches-py/data_batch_5  
cifar-10-batches-py/data_batch_1  
/content/drive/My Drive/cs6353/assignments/assignment2  
Requirement already satisfied: anyio==3.7.1 in /usr/local/lib/python3.10/dist-  
packages (from -r /content/drive/My  
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 1)) (3.7.1)  
Collecting appnope==0.1.3 (from -r /content/drive/My  
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 2))  
  Downloading appnope-0.1.3-py2.py3-none-any.whl.metadata (1.2 kB)  
Requirement already satisfied: argon2-cffi==23.1.0 in  
/usr/local/lib/python3.10/dist-packages (from -r /content/drive/My  
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 3)) (23.1.0)  
Requirement already satisfied: argon2-cffi-bindings==21.2.0 in  
/usr/local/lib/python3.10/dist-packages (from -r /content/drive/My  
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 4)) (21.2.0)  
Collecting arrow==1.2.3 (from -r /content/drive/My  
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 5))  
  Downloading arrow-1.2.3-py3-none-any.whl.metadata (6.9 kB)  
Collecting asttokens==2.2.1 (from -r /content/drive/My  
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 6))  
  Downloading asttokens-2.2.1-py2.py3-none-any.whl.metadata (4.8 kB)  
Collecting async-lru==2.0.4 (from -r /content/drive/My  
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 7))  
  Downloading async_lru-2.0.4-py3-none-any.whl.metadata (4.5 kB)  
Collecting attrs==23.1.0 (from -r /content/drive/My  
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 8))  
  Downloading attrs-23.1.0-py3-none-any.whl.metadata (11 kB)  
Collecting Babel==2.12.1 (from -r /content/drive/My  
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 9))  
  Downloading Babel-2.12.1-py3-none-any.whl.metadata (1.3 kB)  
Requirement already satisfied: backcall==0.2.0 in  
/usr/local/lib/python3.10/dist-packages (from -r /content/drive/My  
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 10)) (0.2.0)  
Collecting beautifulsoup4==4.12.2 (from -r /content/drive/My  
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 11))  
  Downloading beautifulsoup4-4.12.2-py3-none-any.whl.metadata (3.6 kB)  
Collecting bleach==6.0.0 (from -r /content/drive/My  
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 12))
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    Downloading bleach-6.0.0-py3-none-any.whl.metadata (29 kB)
Collecting certifi==2023.7.22 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 13))
    Downloading certifi-2023.7.22-py3-none-any.whl.metadata (2.2 kB)
Collecting cffi==1.15.1 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 14))
    Downloading
cffi-1.15.1-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.whl.metadata
(1.1 kB)
Collecting charset-normalizer==3.2.0 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 15))
    Downloading charset_normalizer-3.2.0-cp310-cp310-manylinux_2_17_x86_64.manylin
ux2014_x86_64.whl.metadata (31 kB)
Collecting comm==0.1.4 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 16))
    Downloading comm-0.1.4-py3-none-any.whl.metadata (4.2 kB)
Collecting contourpy==1.1.0 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 17))
    Downloading contourpy-1.1.0-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x8
6_64.whl.metadata (5.7 kB)
Collecting cycycler==0.11.0 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 18))
    Downloading cycycler-0.11.0-py3-none-any.whl.metadata (785 bytes)
Collecting debugpy==1.6.7.post1 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 19))
    Downloading debugpy-1.6.7.post1-cp310-cp310-manylinux_2_17_x86_64.manylinux201
4_x86_64.whl.metadata (1.1 kB)
Requirement already satisfied: decorator<=5.0 in /usr/local/lib/python3.10/dist-
packages (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 20)) (4.4.2)
Requirement already satisfied: defusedxml==0.7.1 in
/usr/local/lib/python3.10/dist-packages (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 21)) (0.7.1)
Collecting executing==1.2.0 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 22))
    Downloading executing-1.2.0-py2.py3-none-any.whl.metadata (8.9 kB)
Collecting fastjsonschema==2.18.0 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 23))
    Downloading fastjsonschema-2.18.0-py3-none-any.whl.metadata (2.0 kB)
Collecting fonttools==4.42.1 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 24))
    Downloading fonttools-4.42.1-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x
86_64.whl.metadata (150 kB)

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Collecting fqdn==1.5.1 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 25))

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    Downloading fqdn-1.5.1-py3-none-any.whl.metadata (1.4 kB)
Collecting idna==3.4 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 26))
    Downloading idna-3.4-py3-none-any.whl.metadata (9.8 kB)
Collecting imageio==2.31.1 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 27))
    Downloading imageio-2.31.1-py3-none-any.whl.metadata (4.7 kB)
Requirement already satisfied: ipykernel<=5.5.6 in
/usr/local/lib/python3.10/dist-packages (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 28)) (5.5.6)
Requirement already satisfied: ipython<=7.34.0 in
/usr/local/lib/python3.10/dist-packages (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 29)) (7.34.0)
Collecting isoduration==20.11.0 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 30))
    Downloading isoduration-20.11.0-py3-none-any.whl.metadata (5.7 kB)
Collecting jedi==0.19.0 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 31))
    Downloading jedi-0.19.0-py2.py3-none-any.whl.metadata (22 kB)
Collecting Jinja2==3.1.2 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 32))
    Downloading Jinja2-3.1.2-py3-none-any.whl.metadata (3.5 kB)
Collecting json5==0.9.14 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 33))
    Downloading json5-0.9.14-py2.py3-none-any.whl.metadata (10 kB)
Collecting jsonpointer==2.4 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 34))
    Downloading jsonpointer-2.4-py2.py3-none-any.whl.metadata (2.5 kB)
Collecting jsonschema==4.19.0 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 35))
    Downloading jsonschema-4.19.0-py3-none-any.whl.metadata (8.2 kB)
Collecting jsonschema-specifications==2023.7.1 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 36))
    Downloading jsonschema_specifications-2023.7.1-py3-none-any.whl.metadata (2.8
kB)
Collecting jupyter-events==0.7.0 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 37))
    Downloading jupyter_events-0.7.0-py3-none-any.whl.metadata (5.5 kB)
Collecting jupyter-lsp==2.2.0 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 38))
    Downloading jupyter_lsp-2.2.0-py3-none-any.whl.metadata (1.8 kB)
Requirement already satisfied: jupyter_client<8.0 in
/usr/local/lib/python3.10/dist-packages (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 39)) (6.1.12)
Collecting jupyter_core==5.3.1 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 40))
    Downloading jupyter_core-5.3.1-py3-none-any.whl.metadata (3.4 kB)
Collecting jupyter_server==2.7.2 (from -r /content/drive/My

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Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 41))
  Downloading jupyter_server-2.7.2-py3-none-any.whl.metadata (8.6 kB)
Collecting jupyter_server_terminals==0.4.4 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 42))
  Downloading jupyter_server_terminals-0.4.4-py3-none-any.whl.metadata (6.3 kB)
Collecting jupyterlab==4.0.5 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 43))
  Downloading jupyterlab-4.0.5-py3-none-any.whl.metadata (15 kB)
Collecting jupyterlab_pygments==0.2.2 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 44))
  Downloading jupyterlab_pygments-0.2.2-py2.py3-none-any.whl.metadata (1.9 kB)
Collecting jupyterlab_server==2.24.0 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 45))
  Downloading jupyterlab_server-2.24.0-py3-none-any.whl.metadata (5.8 kB)
Collecting kiwisolver==1.4.5 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 46))
  Downloading kiwisolver-1.4.5-cp310-cp310-manylinux_2_12_x86_64.manylinux2010_x
86_64.whl.metadata (6.4 kB)
Collecting MarkupSafe==2.1.3 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 47))
  Downloading MarkupSafe-2.1.3-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x
86_64.whl.metadata (3.0 kB)
Collecting matplotlib==3.7.2 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 48))
  Downloading matplotlib-3.7.2-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x
86_64.whl.metadata (5.6 kB)
Collecting matplotlib-inline==0.1.6 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 49))
  Downloading matplotlib_inline-0.1.6-py3-none-any.whl.metadata (2.8 kB)
Collecting mistune==3.0.1 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 50))
  Downloading mistune-3.0.1-py3-none-any.whl.metadata (1.7 kB)
Collecting nbclient==0.8.0 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 51))
  Downloading nbclient-0.8.0-py3-none-any.whl.metadata (7.8 kB)
Collecting nbconvert==7.7.4 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 52))
  Downloading nbconvert-7.7.4-py3-none-any.whl.metadata (8.0 kB)
Collecting nbformat==5.9.2 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 53))
  Downloading nbformat-5.9.2-py3-none-any.whl.metadata (3.4 kB)
Collecting nest-asyncio==1.5.7 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 54))
  Downloading nest_asyncio-1.5.7-py3-none-any.whl.metadata (2.7 kB)
Collecting notebook_shim==0.2.3 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 55))
  Downloading notebook_shim-0.2.3-py3-none-any.whl.metadata (4.0 kB)
Collecting numpy<1.24,>=1.22 (from -r /content/drive/My

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Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 56))
  Downloading
numpy-1.23.5-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.whl.metadata
(2.3 kB)
Collecting overrides==7.4.0 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 57))
  Downloading overrides-7.4.0-py3-none-any.whl.metadata (5.7 kB)
Collecting packaging==23.1 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 58))
  Downloading packaging-23.1-py3-none-any.whl.metadata (3.1 kB)
Collecting pandas<=1.5.3 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 59))
  Downloading
pandas-1.5.3-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.whl.metadata
(11 kB)
Collecting pandocfilters==1.5.0 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 60))
  Downloading pandocfilters-1.5.0-py2.py3-none-any.whl.metadata (9.0 kB)
Collecting parso==0.8.3 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 61))
  Downloading parso-0.8.3-py2.py3-none-any.whl.metadata (7.5 kB)
Collecting pexpect==4.8.0 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 62))
  Downloading pexpect-4.8.0-py2.py3-none-any.whl.metadata (2.2 kB)
Requirement already satisfied: pickleshare==0.7.5 in
/usr/local/lib/python3.10/dist-packages (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 63)) (0.7.5)
Collecting Pillow==10.0.0 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 64))
  Downloading Pillow-10.0.0-cp310-cp310-manylinux_2_28_x86_64.whl.metadata (9.5
kB)
Collecting platformdirs==3.10.0 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 65))
  Downloading platformdirs-3.10.0-py3-none-any.whl.metadata (11 kB)
Collecting prometheus-client==0.17.1 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 66))
  Downloading prometheus_client-0.17.1-py3-none-any.whl.metadata (24 kB)
Collecting prompt-toolkit==3.0.39 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 67))
  Downloading prompt_toolkit-3.0.39-py3-none-any.whl.metadata (6.4 kB)
Requirement already satisfied: psutil==5.9.5 in /usr/local/lib/python3.10/dist-
packages (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 68)) (5.9.5)
Requirement already satisfied: ptyprocess==0.7.0 in
/usr/local/lib/python3.10/dist-packages (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 69)) (0.7.0)
Collecting pure-eval==0.2.2 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 70))

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Downloading pure_eval-0.2.2-py3-none-any.whl.metadata (6.2 kB)
 Collecting pycparser==2.21 (from -r /content/drive/My
 Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 71))
 Downloading pycparser-2.21-py2.py3-none-any.whl.metadata (1.1 kB)
 Collecting Pygments==2.16.1 (from -r /content/drive/My
 Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 72))
 Downloading Pygments-2.16.1-py3-none-any.whl.metadata (2.5 kB)
 Collecting pyparsing==3.0.9 (from -r /content/drive/My
 Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 73))
 Downloading pyparsing-3.0.9-py3-none-any.whl.metadata (4.2 kB)
 Requirement already satisfied: python-dateutil==2.8.2 in
 /usr/local/lib/python3.10/dist-packages (from -r /content/drive/My
 Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 74)) (2.8.2)
 Collecting python-json-logger==2.0.7 (from -r /content/drive/My
 Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 75))
 Downloading python_json_logger-2.0.7-py3-none-any.whl.metadata (6.5 kB)
 Collecting pytz==2023.3 (from -r /content/drive/My
 Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 76))
 Downloading pytz-2023.3-py2.py3-none-any.whl.metadata (22 kB)
 Collecting PyYAML==6.0.1 (from -r /content/drive/My
 Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 77))
 Downloading
 PyYAML-6.0.1-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.whl.metadata
 (2.1 kB)
 Requirement already satisfied: pyzmq<25 in /usr/local/lib/python3.10/dist-
 packages (from -r /content/drive/My
 Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 78)) (24.0.1)
 Collecting referencing==0.30.2 (from -r /content/drive/My
 Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 79))
 Downloading referencing-0.30.2-py3-none-any.whl.metadata (2.6 kB)
 Collecting requests==2.31.0 (from -r /content/drive/My
 Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 80))
 Downloading requests-2.31.0-py3-none-any.whl.metadata (4.6 kB)
 Collecting rfc3339-validator==0.1.4 (from -r /content/drive/My
 Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 81))
 Downloading rfc3339_validator-0.1.4-py2.py3-none-any.whl.metadata (1.5 kB)
 Collecting rfc3986-validator==0.1.1 (from -r /content/drive/My
 Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 82))
 Downloading rfc3986_validator-0.1.1-py2.py3-none-any.whl.metadata (1.7 kB)
 Collecting rpds-py==0.9.2 (from -r /content/drive/My
 Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 83))
 Downloading rpds_py-0.9.2-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.whl.metadata (3.7 kB)
 Collecting scipy==1.11.2 (from -r /content/drive/My
 Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 84))
 Downloading
 scipy-1.11.2-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.whl.metadata
 (59 kB)

59.1/59.1 kB

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Collecting seaborn==0.12.2 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 85))
  Downloading seaborn-0.12.2-py3-none-any.whl.metadata (5.4 kB)
Collecting Send2Trash==1.8.2 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 86))
  Downloading Send2Trash-1.8.2-py3-none-any.whl.metadata (4.0 kB)
Requirement already satisfied: six==1.16.0 in /usr/local/lib/python3.10/dist-
packages (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 87)) (1.16.0)
Collecting sniffio==1.3.0 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 88))
  Downloading sniffio-1.3.0-py3-none-any.whl.metadata (3.6 kB)
Collecting soupsieve==2.4.1 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 89))
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Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 90))
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Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 92))
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Collecting tornado<=6.3.2 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 93))
  Downloading tornado-6.3.2-cp38-abi3-manylinux_2_5_x86_64.manylinux1_x86_64.man
ylinux_2_17_x86_64.manylinux2014_x86_64.whl.metadata (2.5 kB)
Collecting traitlets==5.9.0 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 94))
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Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 95))
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Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 96))
  Downloading uri_template-1.3.0-py3-none-any.whl.metadata (8.8 kB)
Collecting urllib3==2.0.4 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 97))
  Downloading urllib3-2.0.4-py3-none-any.whl.metadata (6.6 kB)
Collecting wcwidth==0.2.6 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 98))
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Collecting webcolors==1.13 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 99))
  Downloading webcolors-1.13-py3-none-any.whl.metadata (2.6 kB)
```



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Requirement already satisfied: webencodings==0.5.1 in
/usr/local/lib/python3.10/dist-packages (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 100)) (0.5.1)
Collecting websocket-client==1.6.2 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 101))
  Downloading websocket_client-1.6.2-py3-none-any.whl.metadata (7.5 kB)
Requirement already satisfied: exceptiongroup in /usr/local/lib/python3.10/dist-
packages (from anyio==3.7.1->-r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 1)) (1.2.2)
Requirement already satisfied: typing-extensions>=4.0.0 in
/usr/local/lib/python3.10/dist-packages (from async-lru==2.0.4->-r
/content/drive/My Drive/cs6353/assignments/assignment2//colab_requirements.txt
(line 7)) (4.12.2)
Collecting jupyter_client<8.0 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 39))
  Downloading jupyter_client-7.4.9-py3-none-any.whl.metadata (8.5 kB)
Requirement already satisfied: tomli in /usr/local/lib/python3.10/dist-packages
(from jupyterlab==4.0.5->-r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 43)) (2.2.1)
Requirement already satisfied: ipython-genutils in
/usr/local/lib/python3.10/dist-packages (from ipykernel<=5.5.6->-r
/content/drive/My Drive/cs6353/assignments/assignment2//colab_requirements.txt
(line 28)) (0.2.0)
Requirement already satisfied: setuptools>=18.5 in
/usr/local/lib/python3.10/dist-packages (from ipython<=7.34.0->-r
/content/drive/My Drive/cs6353/assignments/assignment2//colab_requirements.txt
(line 29)) (75.1.0)
Requirement already satisfied: entrypoints in /usr/local/lib/python3.10/dist-
packages (from jupyter_client<8.0->-r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 39)) (0.4)
Downloading appnope-0.1.3-py2.py3-none-any.whl (4.4 kB)
Downloading arrow-1.2.3-py3-none-any.whl (66 kB)
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5.8 MB/s eta 0:00:00
Downloading asttokens-2.2.1-py2.py3-none-any.whl (26 kB)
Downloading async_lru-2.0.4-py3-none-any.whl (6.1 kB)
Downloading attrs-23.1.0-py3-none-any.whl (61 kB)
61.2/61.2 kB
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Downloading Babel-2.12.1-py3-none-any.whl (10.1 MB)
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Downloading beautifulsoup4-4.12.2-py3-none-any.whl (142 kB)
143.0/143.0 kB
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Downloading bleach-6.0.0-py3-none-any.whl (162 kB)
162.5/162.5 kB
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ylinux2014_x86_64.whl (201 kB)
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Downloading
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kB)
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debugpy-1.6.7.post1-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.whl
(3.0 MB)
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Downloading fastjsonschema-2.18.0-py3-none-any.whl (23 kB)
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MB)
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Downloading jedi-0.19.0-py2.py3-none-any.whl (1.6 MB)
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Downloading jsonpointer-2.4-py2.py3-none-any.whl (7.8 kB)
Downloading jsonschema-4.19.0-py3-none-any.whl (83 kB)
83.4/83.4 kB

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 3.4/3.4 MB
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 PyYAML-6.0.1-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.whl (705 kB)
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 rpds_py-0.9.2-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.whl (1.2 MB)

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Downloading terminado-0.17.1-py3-none-any.whl (17 kB)
Downloading tinycss2-1.2.1-py3-none-any.whl (21 kB)
Downloading traitlets-5.9.0-py3-none-any.whl (117 kB)

117.4/117.4 kB
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Downloading webcolors-1.13-py3-none-any.whl (14 kB)
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57.0/57.0 kB
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17.1/17.1 MB
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Downloading tornado-6.3.2-cp38-abi3-manylinux_2_5_x86_64.manylinux1_x86_64.manylinux_2_17_x86_64.manylinux2014_x86_64.whl (426 kB)

426.9/426.9 kB
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Installing collected packages: wcwidth, pytz, pure-eval, json5, fastjsonschema, executing, appnope, websocket-client, webcolors, urllib3, uri-template, tzdata, traitlets, tornado, tinycss2, soupsieve, sniffio, Send2Trash, rpds-py, rfc3986-validator, rfc3339-validator, PyYAML, python-json-logger, pyparsing, Pygments, pycparser, prompt-toolkit, prometheus-client, platformdirs, Pillow, pexpect, parso, pandocfilters, packaging, overrides, numpy, nest-asyncio, mistune, MarkupSafe, kiwisolver, jupyterlab-pygments, jsonpointer, idna, fqdn, fonttools, debugpy, cyclo, charset-normalizer, certifi, bleach, Babel, attrs, async-lru, asttokens, terminado, stack-data, scipy, requests, referencing, pandas, matplotlib-inline, jupyter_core, Jinja2, jedi, imageio, contourpy, comm, cffi, beautifulsoup4, arrow, matplotlib, jupyter_server_terminals, jupyter_client, jsonschema-specifications, isoduration, seaborn, jsonschema, nbformat, nbclient, jupyter-events, nbconvert, jupyter_server, notebook_shim, jupyterlab_server, jupyter-lsp, jupyterlab

Attempting uninstall: wcwidth

Found existing installation: wcwidth 0.2.13

Uninstalling wcwidth-0.2.13:

Successfully uninstalled wcwidth-0.2.13

Attempting uninstall: pytz

Found existing installation: pytz 2024.2

Uninstalling pytz-2024.2:

Successfully uninstalled pytz-2024.2

Attempting uninstall: fastjsonschema

Found existing installation: fastjsonschema 2.21.1

Uninstalling fastjsonschema-2.21.1:

Successfully uninstalled fastjsonschema-2.21.1

Attempting uninstall: websocket-client

Found existing installation: websocket-client 1.8.0

Uninstalling websocket-client-1.8.0:

Successfully uninstalled websocket-client-1.8.0

Attempting uninstall: webcolors

Found existing installation: webcolors 24.11.1

Uninstalling webcolors-24.11.1:

Successfully uninstalled webcolors-24.11.1

Attempting uninstall: urllib3

Found existing installation: urllib3 2.2.3

Uninstalling urllib3-2.2.3:

Successfully uninstalled urllib3-2.2.3

Attempting uninstall: tzdata

Found existing installation: tzdata 2024.2

Uninstalling tzdata-2024.2:

Successfully uninstalled tzdata-2024.2

Attempting uninstall: traitlets

Found existing installation: traitlets 5.7.1

Uninstalling traitlets-5.7.1:

Successfully uninstalled traitlets-5.7.1

Attempting uninstall: tornado

Found existing installation: tornado 6.3.3

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Uninstalling tornado-6.3.3:
  Successfully uninstalled tornado-6.3.3
Attempting uninstall: tinycss2
  Found existing installation: tinycss2 1.4.0
  Uninstalling tinycss2-1.4.0:
    Successfully uninstalled tinycss2-1.4.0
Attempting uninstall: soupsieve
  Found existing installation: soupsieve 2.6
  Uninstalling soupsieve-2.6:
    Successfully uninstalled soupsieve-2.6
Attempting uninstall: sniffio
  Found existing installation: sniffio 1.3.1
  Uninstalling sniffio-1.3.1:
    Successfully uninstalled sniffio-1.3.1
Attempting uninstall: Send2Trash
  Found existing installation: Send2Trash 1.8.3
  Uninstalling Send2Trash-1.8.3:
    Successfully uninstalled Send2Trash-1.8.3
Attempting uninstall: rpds-py
  Found existing installation: rpds-py 0.22.3
  Uninstalling rpds-py-0.22.3:
    Successfully uninstalled rpds-py-0.22.3
Attempting uninstall: PyYAML
  Found existing installation: PyYAML 6.0.2
  Uninstalling PyYAML-6.0.2:
    Successfully uninstalled PyYAML-6.0.2
Attempting uninstall: pyparsing
  Found existing installation: pyparsing 3.2.0
  Uninstalling pyparsing-3.2.0:
    Successfully uninstalled pyparsing-3.2.0
Attempting uninstall: Pygments
  Found existing installation: Pygments 2.18.0
  Uninstalling Pygments-2.18.0:
    Successfully uninstalled Pygments-2.18.0
Attempting uninstall: pycparser
  Found existing installation: pycparser 2.22
  Uninstalling pycparser-2.22:
    Successfully uninstalled pycparser-2.22
Attempting uninstall: prompt-toolkit
  Found existing installation: prompt_toolkit 3.0.48
  Uninstalling prompt_toolkit-3.0.48:
    Successfully uninstalled prompt_toolkit-3.0.48
Attempting uninstall: prometheus-client
  Found existing installation: prometheus_client 0.21.1
  Uninstalling prometheus_client-0.21.1:
    Successfully uninstalled prometheus_client-0.21.1
Attempting uninstall: platformdirs
  Found existing installation: platformdirs 4.3.6

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Uninstalling platformdirs-4.3.6:
 Successfully uninstalled platformdirs-4.3.6
Attempting uninstall: Pillow
 Found existing installation: pillow 11.0.0
 Uninstalling pillow-11.0.0:
 Successfully uninstalled pillow-11.0.0
Attempting uninstall: pexpect
 Found existing installation: pexpect 4.9.0
 Uninstalling pexpect-4.9.0:
 Successfully uninstalled pexpect-4.9.0
Attempting uninstall: parso
 Found existing installation: parso 0.8.4
 Uninstalling parso-0.8.4:
 Successfully uninstalled parso-0.8.4
Attempting uninstall: pandocfilters
 Found existing installation: pandocfilters 1.5.1
 Uninstalling pandocfilters-1.5.1:
 Successfully uninstalled pandocfilters-1.5.1
Attempting uninstall: packaging
 Found existing installation: packaging 24.2
 Uninstalling packaging-24.2:
 Successfully uninstalled packaging-24.2
Attempting uninstall: numpy
 Found existing installation: numpy 1.26.4
 Uninstalling numpy-1.26.4:
 Successfully uninstalled numpy-1.26.4
Attempting uninstall: nest-asyncio
 Found existing installation: nest-asyncio 1.6.0
 Uninstalling nest-asyncio-1.6.0:
 Successfully uninstalled nest-asyncio-1.6.0
Attempting uninstall: mistune
 Found existing installation: mistune 3.0.2
 Uninstalling mistune-3.0.2:
 Successfully uninstalled mistune-3.0.2
Attempting uninstall: MarkupSafe
 Found existing installation: MarkupSafe 3.0.2
 Uninstalling MarkupSafe-3.0.2:
 Successfully uninstalled MarkupSafe-3.0.2
Attempting uninstall: kiwisolver
 Found existing installation: kiwisolver 1.4.7
 Uninstalling kiwisolver-1.4.7:
 Successfully uninstalled kiwisolver-1.4.7
Attempting uninstall: jupyterlab-pygments
 Found existing installation: jupyterlab_pygments 0.3.0
 Uninstalling jupyterlab_pygments-0.3.0:
 Successfully uninstalled jupyterlab_pygments-0.3.0
Attempting uninstall: jsonpointer
 Found existing installation: jsonpointer 3.0.0

Uninstalling jsonpointer-3.0.0:
 Successfully uninstalled jsonpointer-3.0.0
Attempting uninstall: idna
 Found existing installation: idna 3.10
 Uninstalling idna-3.10:
 Successfully uninstalled idna-3.10
Attempting uninstall: fonttools
 Found existing installation: fonttools 4.55.1
 Uninstalling fonttools-4.55.1:
 Successfully uninstalled fonttools-4.55.1
Attempting uninstall: debugpy
 Found existing installation: debugpy 1.8.0
 Uninstalling debugpy-1.8.0:
 Successfully uninstalled debugpy-1.8.0
Attempting uninstall: cycler
 Found existing installation: cycler 0.12.1
 Uninstalling cycler-0.12.1:
 Successfully uninstalled cycler-0.12.1
Attempting uninstall: charset-normalizer
 Found existing installation: charset-normalizer 3.4.0
 Uninstalling charset-normalizer-3.4.0:
 Successfully uninstalled charset-normalizer-3.4.0
Attempting uninstall: certifi
 Found existing installation: certifi 2024.8.30
 Uninstalling certifi-2024.8.30:
 Successfully uninstalled certifi-2024.8.30
Attempting uninstall: bleach
 Found existing installation: bleach 6.2.0
 Uninstalling bleach-6.2.0:
 Successfully uninstalled bleach-6.2.0
Attempting uninstall: Babel
 Found existing installation: babel 2.16.0
 Uninstalling babel-2.16.0:
 Successfully uninstalled babel-2.16.0
Attempting uninstall: attrs
 Found existing installation: attrs 24.2.0
 Uninstalling attrs-24.2.0:
 Successfully uninstalled attrs-24.2.0
Attempting uninstall: terminado
 Found existing installation: terminado 0.18.1
 Uninstalling terminado-0.18.1:
 Successfully uninstalled terminado-0.18.1
Attempting uninstall: scipy
 Found existing installation: scipy 1.13.1
 Uninstalling scipy-1.13.1:
 Successfully uninstalled scipy-1.13.1
Attempting uninstall: requests
 Found existing installation: requests 2.32.3

Uninstalling requests-2.32.3:
 Successfully uninstalled requests-2.32.3
Attempting uninstall: referencing
 Found existing installation: referencing 0.35.1
 Uninstalling referencing-0.35.1:
 Successfully uninstalled referencing-0.35.1
Attempting uninstall: pandas
 Found existing installation: pandas 2.2.2
 Uninstalling pandas-2.2.2:
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Attempting uninstall: matplotlib-inline
 Found existing installation: matplotlib-inline 0.1.7
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Attempting uninstall: jupyter_core
 Found existing installation: jupyter_core 5.7.2
 Uninstalling jupyter_core-5.7.2:
 Successfully uninstalled jupyter_core-5.7.2
Attempting uninstall: Jinja2
 Found existing installation: Jinja2 3.1.4
 Uninstalling Jinja2-3.1.4:
 Successfully uninstalled Jinja2-3.1.4
Attempting uninstall: imageio
 Found existing installation: imageio 2.36.1
 Uninstalling imageio-2.36.1:
 Successfully uninstalled imageio-2.36.1
Attempting uninstall: contourpy
 Found existing installation: contourpy 1.3.1
 Uninstalling contourpy-1.3.1:
 Successfully uninstalled contourpy-1.3.1
Attempting uninstall: cffi
 Found existing installation: cffi 1.17.1
 Uninstalling cffi-1.17.1:
 Successfully uninstalled cffi-1.17.1
Attempting uninstall: beautifulsoup4
 Found existing installation: beautifulsoup4 4.12.3
 Uninstalling beautifulsoup4-4.12.3:
 Successfully uninstalled beautifulsoup4-4.12.3
Attempting uninstall: matplotlib
 Found existing installation: matplotlib 3.8.0
 Uninstalling matplotlib-3.8.0:
 Successfully uninstalled matplotlib-3.8.0
Attempting uninstall: jupyter_client
 Found existing installation: jupyter-client 6.1.12
 Uninstalling jupyter-client-6.1.12:
 Successfully uninstalled jupyter-client-6.1.12
Attempting uninstall: jsonschema-specifications
 Found existing installation: jsonschema-specifications 2024.10.1

```
Uninstalling jsonschema-specifications-2024.10.1:
  Successfully uninstalled jsonschema-specifications-2024.10.1
Attempting uninstall: seaborn
  Found existing installation: seaborn 0.13.2
  Uninstalling seaborn-0.13.2:
    Successfully uninstalled seaborn-0.13.2
Attempting uninstall: jsonschema
  Found existing installation: jsonschema 4.23.0
  Uninstalling jsonschema-4.23.0:
    Successfully uninstalled jsonschema-4.23.0
Attempting uninstall: nbformat
  Found existing installation: nbformat 5.10.4
  Uninstalling nbformat-5.10.4:
    Successfully uninstalled nbformat-5.10.4
Attempting uninstall: nbclient
  Found existing installation: nbclient 0.10.1
  Uninstalling nbclient-0.10.1:
    Successfully uninstalled nbclient-0.10.1
Attempting uninstall: nbconvert
  Found existing installation: nbconvert 7.16.4
  Uninstalling nbconvert-7.16.4:
    Successfully uninstalled nbconvert-7.16.4
Attempting uninstall: jupyter_server
  Found existing installation: jupyter-server 1.24.0
  Uninstalling jupyter-server-1.24.0:
    Successfully uninstalled jupyter-server-1.24.0
Attempting uninstall: notebook_shim
  Found existing installation: notebook_shim 0.2.4
  Uninstalling notebook_shim-0.2.4:
    Successfully uninstalled notebook_shim-0.2.4
```

ERROR: pip's dependency resolver does not currently take into account all the packages that are installed. This behaviour is the source of the following dependency conflicts.

albucore 0.0.19 requires numpy>=1.24.4, but you have numpy 1.23.5 which is incompatible.

albumentations 1.4.20 requires numpy>=1.24.4, but you have numpy 1.23.5 which is incompatible.

bigframes 1.27.0 requires numpy>=1.24.0, but you have numpy 1.23.5 which is incompatible.

bokeh 3.6.2 requires contourpy>=1.2, but you have contourpy 1.1.0 which is incompatible.

chex 0.1.87 requires numpy>=1.24.1, but you have numpy 1.23.5 which is incompatible.

cudf-cu12 24.10.1 requires pandas<2.2.3dev0,>=2.0, but you have pandas 1.5.3 which is incompatible.

google-colab 1.0.0 requires pandas==2.2.2, but you have pandas 1.5.3 which is incompatible.

google-colab 1.0.0 requires requests==2.32.3, but you have requests 2.31.0 which is incompatible.

google-colab 1.0.0 requires tornado==6.3.3, but you have tornado 6.3.2 which is incompatible.

jax 0.4.33 requires numpy>=1.24, but you have numpy 1.23.5 which is incompatible.

jaxlib 0.4.33 requires numpy>=1.24, but you have numpy 1.23.5 which is incompatible.

langchain-core 0.3.21 requires packaging<25,>=23.2, but you have packaging 23.1 which is incompatible.

mizani 0.13.0 requires pandas>=2.2.0, but you have pandas 1.5.3 which is incompatible.

plotnine 0.14.3 requires matplotlib>=3.8.0, but you have matplotlib 3.7.2 which is incompatible.

plotnine 0.14.3 requires pandas>=2.2.0, but you have pandas 1.5.3 which is incompatible.

pygit2 1.16.0 requires cffi>=1.17.0, but you have cffi 1.15.1 which is incompatible.

scikit-image 0.24.0 requires imageio>=2.33, but you have imageio 2.31.1 which is incompatible.

Pillow-10.0.0 PyYAML-6.0.1 Pygments-2.16.1 Send2Trash-1.8.2 appnope-0.1.3
 arrow-1.2.3 asttokens-2.2.1 async-lru-2.0.4 attrs-23.1.0 beautifulsoup4-4.12.2
 bleach-6.0.0 certifi-2023.7.22 cffi-1.15.1 charset-normalizer-3.2.0 comm-0.1.4
 contourpy-1.1.0 cycler-0.11.0 debugpy-1.6.7.post1 executing-1.2.0
 fastjsonschema-2.18.0 fonttools-4.42.1 fqdn-1.5.1 idna-3.4 imageio-2.31.1
 isoduration-20.11.0 jedi-0.19.0 json5-0.9.14 jsonpointer-2.4 jsonschema-4.19.0
 jsonschema-specifications-2023.7.1 jupyter-events-0.7.0 jupyter-lsp-2.2.0
 jupyter_client-7.4.9 jupyter_core-5.3.1 jupyter_server-2.7.2
 jupyter_server_terminals-0.4.4 jupyterlab-4.0.5 jupyterlab-pygments-0.2.2
 jupyterlab_server-2.24.0 kiwisolver-1.4.5 matplotlib-3.7.2 matplotlib-
 inline-0.1.6 mistune-3.0.1 nbclient-0.8.0 nbconvert-7.7.4 nbformat-5.9.2 nest-
 asyncio-1.5.7 notebook_shim-0.2.3 numpy-1.23.5 overrides-7.4.0 packaging-23.1
 pandas-1.5.3 pandocfilters-1.5.0 parso-0.8.3 pexpect-4.8.0 platformdirs-3.10.0
 prometheus-client-0.17.1 prompt-toolkit-3.0.39 pure-eval-0.2.2 pycparser-2.21
 pyparsing-3.0.9 python-json-logger-2.0.7 pytz-2023.3 referencing-0.30.2
 requests-2.31.0 rfc3339-validator-0.1.4 rfc3986-validator-0.1.1 rpds-py-0.9.2
 scipy-1.11.2 seaborn-0.12.2 sniffio-1.3.0 soupsieve-2.4.1 stack-data-0.6.2
 terminado-0.17.1 tinycss2-1.2.1 tornado-6.3.2 traitlets-5.9.0 tzdata-2023.3 uri-
 template-1.3.0 urllib3-2.0.4 wcwidth-0.2.6 webcolors-1.13 websocket-client-1.6.2

1 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](#) 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.

```
[2]: from __future__ import print_function
import random
import numpy as np
from cs6353.data_utils import load_CIFAR10
import matplotlib.pyplot as plt

%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
```

1.1 Load data

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

```
[6]: from cs6353.features import color_histogram_hsv, hog_feature
from cs6353.data_utils import load_CIFAR10

def get_CIFAR10_data(cifar10_dir='cs6353/datasets/cifar-10-batches-py',
    ↪num_training=49000, num_validation=1000, num_test=1000):
    # Load the raw CIFAR-10 data
    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 NameError:
    pass

#####
# TODO: Change the path of the CIFAR-10 data directory correctly to #
# the correct location #
# Default path is set to cs6353/datasets/cifar-10-batches-py' #
#####
cifar10_dir='cs6353/datasets/cifar-10-batches-py'

X_train, y_train, X_val, y_val, X_test, y_test = get_CIFAR10_data(cifar10_dir)

print('Train data shape: ', X_train.shape)
```

```

print('Train labels shape: ', y_train.shape)
print('Validation data shape: ', X_val.shape)
print('Validation labels shape: ', y_val.shape)
print('Test data shape: ', X_test.shape)
print('Test labels shape: ', y_test.shape)
#####
#                               END OF YOUR CODE                               #
#####

```

```

Train data shape: (49000, 32, 32, 3)
Train labels shape: (49000,)
Validation data shape: (1000, 32, 32, 3)
Validation labels shape: (1000,)
Test data shape: (1000, 32, 32, 3)
Test labels shape: (1000,)

```

1.2 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.

```

[23]: from cs6353.features import *

num_color_bins = 20 # Increase the number of bins for better feature
    ↪ representation
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.shape[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))])

```

```

Done extracting features for 1000 / 49000 images
Done extracting features for 2000 / 49000 images
Done extracting features for 3000 / 49000 images
Done extracting features for 4000 / 49000 images
Done extracting features for 5000 / 49000 images
Done extracting features for 6000 / 49000 images
Done extracting features for 7000 / 49000 images
Done extracting features for 8000 / 49000 images
Done extracting features for 9000 / 49000 images
Done extracting features for 10000 / 49000 images
Done extracting features for 11000 / 49000 images
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Done extracting features for 31000 / 49000 images
Done extracting features for 32000 / 49000 images
Done extracting features for 33000 / 49000 images
Done extracting features for 34000 / 49000 images
Done extracting features for 35000 / 49000 images
Done extracting features for 36000 / 49000 images
Done extracting features for 37000 / 49000 images

```



```

Done extracting features for 38000 / 49000 images
Done extracting features for 39000 / 49000 images
Done extracting features for 40000 / 49000 images
Done extracting features for 41000 / 49000 images
Done extracting features for 42000 / 49000 images
Done extracting features for 43000 / 49000 images
Done extracting features for 44000 / 49000 images
Done extracting features for 45000 / 49000 images
Done extracting features for 46000 / 49000 images
Done extracting features for 47000 / 49000 images
Done extracting features for 48000 / 49000 images

```

1.3 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.

```

[38]: # Use the validation set to tune the learning rate and regularization strength

from cs6353.classifiers.linear_classifier import LinearSVM

learning_rates = [5e-9, 6e-9, 6.5e-9, 7e-9, 7.5e-9, 8e-9]
regularization_strengths = [5.5e6, 6e6, 6.5e6, 6.75e6, 7e6, 7.5e6]

num_color_bins = 25 # Increased number of bins
feature_fns = [hog_feature, lambda img: color_histogram_hsv(img,
    ↪nbin=num_color_bins)]

# Normalize features
mean_feat = np.mean(X_train_feats, axis=0)
std_feat = np.std(X_train_feats, axis=0)
X_train_feats = (X_train_feats - mean_feat) / (std_feat + 1e-6)
X_val_feats = (X_val_feats - mean_feat) / (std_feat + 1e-6)
X_test_feats = (X_test_feats - mean_feat) / (std_feat + 1e-6)

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 SVM; save #
# the best trained classifier in best_svm. You might also want to play #
# with different numbers of bins in the color histogram. If you are careful #
# you should be able to get accuracy of near 0.44 on the validation set. #
#####

```

```

for lr in learning_rates:
    for reg in regularization_strengths:
        print(f"Training with lr={lr}, reg={reg}")

        svm = LinearSVM()
        loss_hist = svm.train(
            X_train_feats, y_train,
            learning_rate=lr,
            reg=reg,
            num_iters=10000, # Increased iterations
            verbose=True # Monitor progress
        )

        y_train_pred = svm.predict(X_train_feats)
        train_accuracy = np.mean(y_train_pred == y_train)
        y_val_pred = svm.predict(X_val_feats)
        val_accuracy = np.mean(y_val_pred == y_val)

        results[(lr, reg)] = (train_accuracy, val_accuracy)

        if val_accuracy > best_val:
            best_val = val_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)

```

```

Training with lr=5e-09, reg=5500000.0
iteration 0 / 10000: loss 8852.123110
iteration 100 / 10000: loss 9.107898
iteration 200 / 10000: loss 8.999997

```

iteration 300 / 10000: loss 8.999997
iteration 400 / 10000: loss 8.999997
iteration 500 / 10000: loss 8.999997
iteration 600 / 10000: loss 8.999998
iteration 700 / 10000: loss 8.999997
iteration 800 / 10000: loss 8.999997
iteration 900 / 10000: loss 8.999996
iteration 1000 / 10000: loss 8.999997
iteration 1100 / 10000: loss 8.999997
iteration 1200 / 10000: loss 8.999997
iteration 1300 / 10000: loss 8.999996
iteration 1400 / 10000: loss 8.999996
iteration 1500 / 10000: loss 8.999997
iteration 1600 / 10000: loss 8.999997
iteration 1700 / 10000: loss 8.999996
iteration 1800 / 10000: loss 8.999997
iteration 1900 / 10000: loss 8.999997
iteration 2000 / 10000: loss 8.999997
iteration 2100 / 10000: loss 8.999996
iteration 2200 / 10000: loss 8.999997
iteration 2300 / 10000: loss 8.999997
iteration 2400 / 10000: loss 8.999997
iteration 2500 / 10000: loss 8.999997
iteration 2600 / 10000: loss 8.999997
iteration 2700 / 10000: loss 8.999997
iteration 2800 / 10000: loss 8.999996
iteration 2900 / 10000: loss 8.999997
iteration 3000 / 10000: loss 8.999997
iteration 3100 / 10000: loss 8.999997
iteration 3200 / 10000: loss 8.999996
iteration 3300 / 10000: loss 8.999997
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iteration 3600 / 10000: loss 8.999997
iteration 3700 / 10000: loss 8.999996
iteration 3800 / 10000: loss 8.999997
iteration 3900 / 10000: loss 8.999998
iteration 4000 / 10000: loss 8.999996
iteration 4100 / 10000: loss 8.999996
iteration 4200 / 10000: loss 8.999996
iteration 4300 / 10000: loss 8.999997
iteration 4400 / 10000: loss 8.999997
iteration 4500 / 10000: loss 8.999997
iteration 4600 / 10000: loss 8.999997
iteration 4700 / 10000: loss 8.999997
iteration 4800 / 10000: loss 8.999996
iteration 4900 / 10000: loss 8.999997
iteration 5000 / 10000: loss 8.999997

iteration 5100 / 10000: loss 8.999997
iteration 5200 / 10000: loss 8.999996
iteration 5300 / 10000: loss 8.999996
iteration 5400 / 10000: loss 8.999997
iteration 5500 / 10000: loss 8.999997
iteration 5600 / 10000: loss 8.999996
iteration 5700 / 10000: loss 8.999997
iteration 5800 / 10000: loss 8.999996
iteration 5900 / 10000: loss 8.999996
iteration 6000 / 10000: loss 8.999996
iteration 6100 / 10000: loss 8.999997
iteration 6200 / 10000: loss 8.999997
iteration 6300 / 10000: loss 8.999997
iteration 6400 / 10000: loss 8.999997
iteration 6500 / 10000: loss 8.999997
iteration 6600 / 10000: loss 8.999997
iteration 6700 / 10000: loss 8.999997
iteration 6800 / 10000: loss 8.999996
iteration 6900 / 10000: loss 8.999997
iteration 7000 / 10000: loss 8.999997
iteration 7100 / 10000: loss 8.999997
iteration 7200 / 10000: loss 8.999997
iteration 7300 / 10000: loss 8.999996
iteration 7400 / 10000: loss 8.999997
iteration 7500 / 10000: loss 8.999997
iteration 7600 / 10000: loss 8.999997
iteration 7700 / 10000: loss 8.999996
iteration 7800 / 10000: loss 8.999998
iteration 7900 / 10000: loss 8.999997
iteration 8000 / 10000: loss 8.999998
iteration 8100 / 10000: loss 8.999997
iteration 8200 / 10000: loss 8.999997
iteration 8300 / 10000: loss 8.999997
iteration 8400 / 10000: loss 8.999997
iteration 8500 / 10000: loss 8.999997
iteration 8600 / 10000: loss 8.999997
iteration 8700 / 10000: loss 8.999996
iteration 8800 / 10000: loss 8.999997
iteration 8900 / 10000: loss 8.999997
iteration 9000 / 10000: loss 8.999996
iteration 9100 / 10000: loss 8.999996
iteration 9200 / 10000: loss 8.999997
iteration 9300 / 10000: loss 8.999998
iteration 9400 / 10000: loss 8.999996
iteration 9500 / 10000: loss 8.999997
iteration 9600 / 10000: loss 8.999996
iteration 9700 / 10000: loss 8.999997
iteration 9800 / 10000: loss 8.999997

iteration 9900 / 10000: loss 8.999996
Training with lr=5e-09, reg=6000000.0
iteration 0 / 10000: loss 9341.075537
iteration 100 / 10000: loss 9.039403
iteration 200 / 10000: loss 8.999996
iteration 300 / 10000: loss 8.999997
iteration 400 / 10000: loss 8.999997
iteration 500 / 10000: loss 8.999997
iteration 600 / 10000: loss 8.999997
iteration 700 / 10000: loss 8.999997
iteration 800 / 10000: loss 8.999997
iteration 900 / 10000: loss 8.999997
iteration 1000 / 10000: loss 8.999998
iteration 1100 / 10000: loss 8.999997
iteration 1200 / 10000: loss 8.999998
iteration 1300 / 10000: loss 8.999998
iteration 1400 / 10000: loss 8.999997
iteration 1500 / 10000: loss 8.999997
iteration 1600 / 10000: loss 8.999996
iteration 1700 / 10000: loss 8.999997
iteration 1800 / 10000: loss 8.999997
iteration 1900 / 10000: loss 8.999996
iteration 2000 / 10000: loss 8.999996
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iteration 9400 / 10000: loss 8.999997
iteration 9500 / 10000: loss 8.999997
iteration 9600 / 10000: loss 8.999997
iteration 9700 / 10000: loss 8.999997
iteration 9800 / 10000: loss 8.999997
iteration 9900 / 10000: loss 8.999997
Training with lr=5e-09, reg=6500000.0
iteration 0 / 10000: loss 10559.991534
iteration 100 / 10000: loss 9.015326
iteration 200 / 10000: loss 8.999997
iteration 300 / 10000: loss 8.999997
iteration 400 / 10000: loss 8.999997
iteration 500 / 10000: loss 8.999997
iteration 600 / 10000: loss 8.999998
iteration 700 / 10000: loss 8.999996
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iteration 4000 / 10000: loss 8.999997
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iteration 4100 / 10000: loss 8.999997
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iteration 8900 / 10000: loss 8.999997
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iteration 9800 / 10000: loss 8.999997
iteration 9900 / 10000: loss 8.999997
Training with lr=5e-09, reg=6750000.0
iteration 0 / 10000: loss 10528.833547
iteration 100 / 10000: loss 9.008938
iteration 200 / 10000: loss 8.999997
iteration 300 / 10000: loss 8.999997
iteration 400 / 10000: loss 8.999998
iteration 500 / 10000: loss 8.999997
iteration 600 / 10000: loss 8.999998
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iteration 3600 / 10000: loss 8.999998
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iteration 8400 / 10000: loss 8.999998
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iteration 9700 / 10000: loss 8.999997
iteration 9800 / 10000: loss 8.999998
iteration 9900 / 10000: loss 8.999998
Training with lr=5e-09, reg=7000000.0
iteration 0 / 10000: loss 11269.609264
iteration 100 / 10000: loss 9.005592
iteration 200 / 10000: loss 8.999998
iteration 300 / 10000: loss 8.999997
iteration 400 / 10000: loss 8.999997
iteration 500 / 10000: loss 8.999998
iteration 600 / 10000: loss 8.999997
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iteration 2900 / 10000: loss 8.999998
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iteration 3100 / 10000: loss 8.999998
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iteration 7900 / 10000: loss 8.999998
iteration 8000 / 10000: loss 8.999998
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iteration 9600 / 10000: loss 8.999998
iteration 9700 / 10000: loss 8.999998
iteration 9800 / 10000: loss 8.999998
iteration 9900 / 10000: loss 8.999997
Training with lr=5e-09, reg=7500000.0
iteration 0 / 10000: loss 12436.978378
iteration 100 / 10000: loss 9.002099
iteration 200 / 10000: loss 8.999997
iteration 300 / 10000: loss 8.999998
iteration 400 / 10000: loss 8.999997
iteration 500 / 10000: loss 8.999998
iteration 600 / 10000: loss 8.999998
iteration 700 / 10000: loss 8.999997
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iteration 2600 / 10000: loss 8.999997
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iteration 9600 / 10000: loss 8.999998
iteration 9700 / 10000: loss 8.999998
iteration 9800 / 10000: loss 8.999998
iteration 9900 / 10000: loss 8.999998
Training with lr=6e-09, reg=5500000.0
iteration 0 / 10000: loss 8864.790234
iteration 100 / 10000: loss 9.010400
iteration 200 / 10000: loss 8.999997
iteration 300 / 10000: loss 8.999997
iteration 400 / 10000: loss 8.999996
iteration 500 / 10000: loss 8.999997
iteration 600 / 10000: loss 8.999997
iteration 700 / 10000: loss 8.999997
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iteration 1900 / 10000: loss 8.999996
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iteration 2100 / 10000: loss 8.999997
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iteration 6900 / 10000: loss 8.999997
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iteration 9800 / 10000: loss 8.999996
iteration 9900 / 10000: loss 8.999997
Training with lr=6e-09, reg=6000000.0
iteration 0 / 10000: loss 9883.049642
iteration 100 / 10000: loss 9.003189
iteration 200 / 10000: loss 8.999997
iteration 300 / 10000: loss 8.999997
iteration 400 / 10000: loss 8.999997
iteration 500 / 10000: loss 8.999996
iteration 600 / 10000: loss 8.999997
iteration 700 / 10000: loss 8.999997
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iteration 1000 / 10000: loss 8.999997
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iteration 1500 / 10000: loss 8.999997
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iteration 1600 / 10000: loss 8.999996
iteration 1700 / 10000: loss 8.999997
iteration 1800 / 10000: loss 8.999997
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iteration 6400 / 10000: loss 8.999997
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iteration 9700 / 10000: loss 8.999997
iteration 9800 / 10000: loss 8.999997
iteration 9900 / 10000: loss 8.999997
Training with lr=6e-09, reg=6500000.0
iteration 0 / 10000: loss 10302.751269
iteration 100 / 10000: loss 9.000907
iteration 200 / 10000: loss 8.999997
iteration 300 / 10000: loss 8.999997
iteration 400 / 10000: loss 8.999998
iteration 500 / 10000: loss 8.999998
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iteration 1100 / 10000: loss 8.999998
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iteration 9800 / 10000: loss 8.999997
iteration 9900 / 10000: loss 8.999997
Training with lr=6e-09, reg=6750000.0
iteration 0 / 10000: loss 11530.646531
iteration 100 / 10000: loss 9.000526
iteration 200 / 10000: loss 8.999998
iteration 300 / 10000: loss 8.999997
iteration 400 / 10000: loss 8.999997
iteration 500 / 10000: loss 8.999997
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iteration 600 / 10000: loss 8.999997
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iteration 9800 / 10000: loss 8.999997
iteration 9900 / 10000: loss 8.999997
Training with lr=6e-09, reg=7000000.0
iteration 0 / 10000: loss 11451.786437
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iteration 100 / 10000: loss 9.000269
iteration 200 / 10000: loss 8.999997
iteration 300 / 10000: loss 8.999997
iteration 400 / 10000: loss 8.999997
iteration 500 / 10000: loss 8.999998
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iteration 9700 / 10000: loss 8.999998
iteration 9800 / 10000: loss 8.999998
iteration 9900 / 10000: loss 8.999998
Training with lr=6e-09, reg=7500000.0
iteration 0 / 10000: loss 11632.335470
iteration 100 / 10000: loss 9.000072
iteration 200 / 10000: loss 8.999998
iteration 300 / 10000: loss 8.999998
iteration 400 / 10000: loss 8.999998
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iteration 9200 / 10000: loss 8.999997
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iteration 9600 / 10000: loss 8.999997
iteration 9700 / 10000: loss 8.999998
iteration 9800 / 10000: loss 8.999998
iteration 9900 / 10000: loss 8.999997
Training with lr=6.5e-09, reg=5500000.0
iteration 0 / 10000: loss 9272.710671
iteration 100 / 10000: loss 9.003336
iteration 200 / 10000: loss 8.999996
iteration 300 / 10000: loss 8.999998
iteration 400 / 10000: loss 8.999997
iteration 500 / 10000: loss 8.999997
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iteration 3900 / 10000: loss 8.999997
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iteration 8400 / 10000: loss 8.999996
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iteration 8700 / 10000: loss 8.999997
iteration 8800 / 10000: loss 8.999996
iteration 8900 / 10000: loss 8.999997
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iteration 9600 / 10000: loss 8.999998
iteration 9700 / 10000: loss 8.999996
iteration 9800 / 10000: loss 8.999997
iteration 9900 / 10000: loss 8.999996
Training with lr=6.5e-09, reg=6000000.0
iteration 0 / 10000: loss 9921.784489
iteration 100 / 10000: loss 9.000870
iteration 200 / 10000: loss 8.999997
iteration 300 / 10000: loss 8.999997
iteration 400 / 10000: loss 8.999997
iteration 500 / 10000: loss 8.999998
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iteration 3400 / 10000: loss 8.999996
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iteration 9800 / 10000: loss 8.999997
iteration 9900 / 10000: loss 8.999997
Training with lr=6.5e-09, reg=6500000.0
iteration 0 / 10000: loss 10123.246386
iteration 100 / 10000: loss 9.000215
iteration 200 / 10000: loss 8.999997
iteration 300 / 10000: loss 8.999997
iteration 400 / 10000: loss 8.999998
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iteration 9900 / 10000: loss 8.999998
Training with lr=6.5e-09, reg=6750000.0
iteration 0 / 10000: loss 11357.385142
iteration 100 / 10000: loss 9.000116
iteration 200 / 10000: loss 8.999998
iteration 300 / 10000: loss 8.999998
iteration 400 / 10000: loss 8.999997
iteration 500 / 10000: loss 8.999998
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iteration 9800 / 10000: loss 8.999998
iteration 9900 / 10000: loss 8.999997
Training with lr=6.5e-09, reg=7000000.0
iteration 0 / 10000: loss 12032.354900
iteration 100 / 10000: loss 9.000060
iteration 200 / 10000: loss 8.999998
iteration 300 / 10000: loss 8.999997
iteration 400 / 10000: loss 8.999997
iteration 500 / 10000: loss 8.999997
iteration 600 / 10000: loss 8.999998
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iteration 9800 / 10000: loss 8.999998
iteration 9900 / 10000: loss 8.999998
Training with lr=6.5e-09, reg=7500000.0
iteration 0 / 10000: loss 12791.602295
iteration 100 / 10000: loss 9.000013
iteration 200 / 10000: loss 8.999998
iteration 300 / 10000: loss 8.999998
iteration 400 / 10000: loss 8.999998
iteration 500 / 10000: loss 8.999997
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iteration 1400 / 10000: loss 8.999998
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iteration 9700 / 10000: loss 8.999997
iteration 9800 / 10000: loss 8.999997
iteration 9900 / 10000: loss 8.999997
Training with lr=7e-09, reg=5500000.0
iteration 0 / 10000: loss 9316.847038
iteration 100 / 10000: loss 9.001014
iteration 200 / 10000: loss 8.999996
iteration 300 / 10000: loss 8.999997
iteration 400 / 10000: loss 8.999996
iteration 500 / 10000: loss 8.999997
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iteration 900 / 10000: loss 8.999997
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iteration 6500 / 10000: loss 8.999997
iteration 6600 / 10000: loss 8.999997
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iteration 9600 / 10000: loss 8.999996
iteration 9700 / 10000: loss 8.999996
iteration 9800 / 10000: loss 8.999996
iteration 9900 / 10000: loss 8.999996
Training with lr=7e-09, reg=6000000.0
iteration 0 / 10000: loss 10219.618368
iteration 100 / 10000: loss 9.000240
iteration 200 / 10000: loss 8.999997
iteration 300 / 10000: loss 8.999997
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iteration 400 / 10000: loss 8.999997
iteration 500 / 10000: loss 8.999997
iteration 600 / 10000: loss 8.999998
iteration 700 / 10000: loss 8.999997
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iteration 9900 / 10000: loss 8.999997

Training with lr=7e-09, reg=6500000.0
iteration 0 / 10000: loss 10603.162974
iteration 100 / 10000: loss 9.000052
iteration 200 / 10000: loss 8.999998
iteration 300 / 10000: loss 8.999997
iteration 400 / 10000: loss 8.999997
iteration 500 / 10000: loss 8.999998
iteration 600 / 10000: loss 8.999998
iteration 700 / 10000: loss 8.999997
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iteration 9500 / 10000: loss 8.999997
iteration 9600 / 10000: loss 8.999998
iteration 9700 / 10000: loss 8.999997
iteration 9800 / 10000: loss 8.999997
iteration 9900 / 10000: loss 8.999998
Training with lr=7e-09, reg=6750000.0
iteration 0 / 10000: loss 11373.910016
iteration 100 / 10000: loss 9.000025
iteration 200 / 10000: loss 8.999998
iteration 300 / 10000: loss 8.999998
iteration 400 / 10000: loss 8.999997
iteration 500 / 10000: loss 8.999997
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iteration 9800 / 10000: loss 8.999997
iteration 9900 / 10000: loss 8.999998
Training with lr=7e-09, reg=7000000.0
iteration 0 / 10000: loss 11018.123907
iteration 100 / 10000: loss 9.000009
iteration 200 / 10000: loss 8.999998
iteration 300 / 10000: loss 8.999997
iteration 400 / 10000: loss 8.999997
iteration 500 / 10000: loss 8.999998
iteration 600 / 10000: loss 8.999998
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iteration 3700 / 10000: loss 8.999998
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iteration 9800 / 10000: loss 8.999997
iteration 9900 / 10000: loss 8.999997
Training with lr=7e-09, reg=7500000.0
iteration 0 / 10000: loss 12262.142850
iteration 100 / 10000: loss 9.000000
iteration 200 / 10000: loss 8.999998
iteration 300 / 10000: loss 8.999998
iteration 400 / 10000: loss 8.999998
iteration 500 / 10000: loss 8.999998
iteration 600 / 10000: loss 8.999998
iteration 700 / 10000: loss 8.999998
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iteration 3200 / 10000: loss 8.999998
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iteration 8000 / 10000: loss 8.999998
iteration 8100 / 10000: loss 8.999998
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iteration 9700 / 10000: loss 8.999998
iteration 9800 / 10000: loss 8.999997
iteration 9900 / 10000: loss 8.999998
Training with lr=7.5e-09, reg=5500000.0
iteration 0 / 10000: loss 8572.648628
iteration 100 / 10000: loss 9.000282
iteration 200 / 10000: loss 8.999996
iteration 300 / 10000: loss 8.999996
iteration 400 / 10000: loss 8.999997
iteration 500 / 10000: loss 8.999997
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iteration 2700 / 10000: loss 8.999997
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iteration 9800 / 10000: loss 8.999997
iteration 9900 / 10000: loss 8.999996
Training with lr=7.5e-09, reg=6000000.0
iteration 0 / 10000: loss 10204.027429
iteration 100 / 10000: loss 9.000063
iteration 200 / 10000: loss 8.999996
iteration 300 / 10000: loss 8.999998
iteration 400 / 10000: loss 8.999998
iteration 500 / 10000: loss 8.999997
iteration 600 / 10000: loss 8.999997
iteration 700 / 10000: loss 8.999996
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iteration 9800 / 10000: loss 8.999998
iteration 9900 / 10000: loss 8.999997
Training with lr=7.5e-09, reg=6500000.0
iteration 0 / 10000: loss 10701.593803
iteration 100 / 10000: loss 9.000011
iteration 200 / 10000: loss 8.999997
iteration 300 / 10000: loss 8.999998
iteration 400 / 10000: loss 8.999997
iteration 500 / 10000: loss 8.999998
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iteration 1700 / 10000: loss 8.999997
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iteration 9800 / 10000: loss 8.999997
iteration 9900 / 10000: loss 8.999997
Training with lr=7.5e-09, reg=6750000.0
iteration 0 / 10000: loss 11238.167634
iteration 100 / 10000: loss 9.000003
iteration 200 / 10000: loss 8.999998
iteration 300 / 10000: loss 8.999997
iteration 400 / 10000: loss 8.999997
iteration 500 / 10000: loss 8.999997
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iteration 700 / 10000: loss 8.999998
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iteration 1000 / 10000: loss 8.999997
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iteration 1200 / 10000: loss 8.999997
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iteration 6000 / 10000: loss 8.999997
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iteration 9800 / 10000: loss 8.999997
iteration 9900 / 10000: loss 8.999997
Training with lr=7.5e-09, reg=7000000.0
iteration 0 / 10000: loss 11406.753404
iteration 100 / 10000: loss 9.000000
iteration 200 / 10000: loss 8.999997
iteration 300 / 10000: loss 8.999997
iteration 400 / 10000: loss 8.999997
iteration 500 / 10000: loss 8.999998
iteration 600 / 10000: loss 8.999997
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iteration 700 / 10000: loss 8.999998
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iteration 9600 / 10000: loss 8.999998
iteration 9700 / 10000: loss 8.999998
iteration 9800 / 10000: loss 8.999998
iteration 9900 / 10000: loss 8.999998
Training with lr=7.5e-09, reg=7500000.0
iteration 0 / 10000: loss 11886.639739
iteration 100 / 10000: loss 8.999998

iteration 200 / 10000: loss 8.999998
iteration 300 / 10000: loss 8.999997
iteration 400 / 10000: loss 8.999998
iteration 500 / 10000: loss 8.999998
iteration 600 / 10000: loss 8.999998
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iteration 800 / 10000: loss 8.999998
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iteration 5000 / 10000: loss 8.999998
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iteration 9500 / 10000: loss 8.999998
iteration 9600 / 10000: loss 8.999998
iteration 9700 / 10000: loss 8.999998

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iteration 9800 / 10000: loss 8.999998
iteration 9900 / 10000: loss 8.999998
Training with lr=8e-09, reg=5500000.0
iteration 0 / 10000: loss 9071.742520
iteration 100 / 10000: loss 9.000088
iteration 200 / 10000: loss 8.999996
iteration 300 / 10000: loss 8.999997
iteration 400 / 10000: loss 8.999997
iteration 500 / 10000: loss 8.999997
iteration 600 / 10000: loss 8.999996
iteration 700 / 10000: loss 8.999997
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iteration 2800 / 10000: loss 8.999996
iteration 2900 / 10000: loss 8.999996
iteration 3000 / 10000: loss 8.999998
iteration 3100 / 10000: loss 8.999997
iteration 3200 / 10000: loss 8.999997
iteration 3300 / 10000: loss 8.999997
iteration 3400 / 10000: loss 8.999996
iteration 3500 / 10000: loss 8.999996
iteration 3600 / 10000: loss 8.999997
iteration 3700 / 10000: loss 8.999997
iteration 3800 / 10000: loss 8.999998
iteration 3900 / 10000: loss 8.999997
iteration 4000 / 10000: loss 8.999997
iteration 4100 / 10000: loss 8.999996
iteration 4200 / 10000: loss 8.999997
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iteration 4400 / 10000: loss 8.999997
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iteration 4500 / 10000: loss 8.999997
iteration 4600 / 10000: loss 8.999997
iteration 4700 / 10000: loss 8.999997
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iteration 8900 / 10000: loss 8.999996
iteration 9000 / 10000: loss 8.999998
iteration 9100 / 10000: loss 8.999997
iteration 9200 / 10000: loss 8.999998

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iteration 9300 / 10000: loss 8.999997
iteration 9400 / 10000: loss 8.999996
iteration 9500 / 10000: loss 8.999997
iteration 9600 / 10000: loss 8.999997
iteration 9700 / 10000: loss 8.999996
iteration 9800 / 10000: loss 8.999996
iteration 9900 / 10000: loss 8.999997
Training with lr=8e-09, reg=6000000.0
iteration 0 / 10000: loss 9570.177796
iteration 100 / 10000: loss 9.000014
iteration 200 / 10000: loss 8.999998
iteration 300 / 10000: loss 8.999998
iteration 400 / 10000: loss 8.999997
iteration 500 / 10000: loss 8.999997
iteration 600 / 10000: loss 8.999998
iteration 700 / 10000: loss 8.999997
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iteration 4000 / 10000: loss 8.999997
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iteration 4200 / 10000: loss 8.999996
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iteration 8800 / 10000: loss 8.999997
iteration 8900 / 10000: loss 8.999997
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iteration 9600 / 10000: loss 8.999997
iteration 9700 / 10000: loss 8.999998
iteration 9800 / 10000: loss 8.999997
iteration 9900 / 10000: loss 8.999996
Training with lr=8e-09, reg=6500000.0
iteration 0 / 10000: loss 10249.528989
iteration 100 / 10000: loss 9.000000
iteration 200 / 10000: loss 8.999997
iteration 300 / 10000: loss 8.999997
iteration 400 / 10000: loss 8.999998
iteration 500 / 10000: loss 8.999997
iteration 600 / 10000: loss 8.999998
iteration 700 / 10000: loss 8.999997
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iteration 3500 / 10000: loss 8.999998
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iteration 8300 / 10000: loss 8.999998
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iteration 9600 / 10000: loss 8.999998
iteration 9700 / 10000: loss 8.999996
iteration 9800 / 10000: loss 8.999997
iteration 9900 / 10000: loss 8.999998
Training with lr=8e-09, reg=6750000.0
iteration 0 / 10000: loss 10874.610323
iteration 100 / 10000: loss 8.999999
iteration 200 / 10000: loss 8.999997
iteration 300 / 10000: loss 8.999998
iteration 400 / 10000: loss 8.999997
iteration 500 / 10000: loss 8.999998
iteration 600 / 10000: loss 8.999998
iteration 700 / 10000: loss 8.999998
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iteration 2200 / 10000: loss 8.999999
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iteration 3000 / 10000: loss 8.999998
iteration 3100 / 10000: loss 8.999997
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iteration 7800 / 10000: loss 8.999997
iteration 7900 / 10000: loss 8.999997
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iteration 9600 / 10000: loss 8.999997
iteration 9700 / 10000: loss 8.999998
iteration 9800 / 10000: loss 8.999997
iteration 9900 / 10000: loss 8.999998
Training with lr=8e-09, reg=7000000.0
iteration 0 / 10000: loss 10956.582407
iteration 100 / 10000: loss 8.999997
iteration 200 / 10000: loss 8.999998
iteration 300 / 10000: loss 8.999997
iteration 400 / 10000: loss 8.999997
iteration 500 / 10000: loss 8.999998
iteration 600 / 10000: loss 8.999997
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iteration 2500 / 10000: loss 8.999998
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iteration 9600 / 10000: loss 8.999998
iteration 9700 / 10000: loss 8.999998
iteration 9800 / 10000: loss 8.999997
iteration 9900 / 10000: loss 8.999998
Training with lr=8e-09, reg=7500000.0
iteration 0 / 10000: loss 12171.837139
iteration 100 / 10000: loss 8.999997
iteration 200 / 10000: loss 8.999998
iteration 300 / 10000: loss 8.999998
iteration 400 / 10000: loss 8.999998
iteration 500 / 10000: loss 8.999997
iteration 600 / 10000: loss 8.999998
iteration 700 / 10000: loss 8.999998
iteration 800 / 10000: loss 8.999998
iteration 900 / 10000: loss 8.999998
iteration 1000 / 10000: loss 8.999998
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iteration 6800 / 10000: loss 8.999998
iteration 6900 / 10000: loss 8.999998
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iteration 9700 / 10000: loss 8.999998
iteration 9800 / 10000: loss 8.999998
iteration 9900 / 10000: loss 8.999997
lr 5.000000e-09 reg 5.500000e+06 train accuracy: 0.419061 val accuracy: 0.417000
lr 5.000000e-09 reg 6.000000e+06 train accuracy: 0.419878 val accuracy: 0.426000
lr 5.000000e-09 reg 6.500000e+06 train accuracy: 0.414000 val accuracy: 0.409000
lr 5.000000e-09 reg 6.750000e+06 train accuracy: 0.410898 val accuracy: 0.406000
lr 5.000000e-09 reg 7.000000e+06 train accuracy: 0.416673 val accuracy: 0.420000
lr 5.000000e-09 reg 7.500000e+06 train accuracy: 0.410510 val accuracy: 0.420000
lr 6.000000e-09 reg 5.500000e+06 train accuracy: 0.415571 val accuracy: 0.419000
lr 6.000000e-09 reg 6.000000e+06 train accuracy: 0.414776 val accuracy: 0.405000
lr 6.000000e-09 reg 6.500000e+06 train accuracy: 0.412469 val accuracy: 0.407000
lr 6.000000e-09 reg 6.750000e+06 train accuracy: 0.412653 val accuracy: 0.406000
lr 6.000000e-09 reg 7.000000e+06 train accuracy: 0.417878 val accuracy: 0.421000
lr 6.000000e-09 reg 7.500000e+06 train accuracy: 0.418878 val accuracy: 0.421000
lr 6.500000e-09 reg 5.500000e+06 train accuracy: 0.416551 val accuracy: 0.409000
lr 6.500000e-09 reg 6.000000e+06 train accuracy: 0.411490 val accuracy: 0.396000
lr 6.500000e-09 reg 6.500000e+06 train accuracy: 0.408837 val accuracy: 0.420000
lr 6.500000e-09 reg 6.750000e+06 train accuracy: 0.413408 val accuracy: 0.420000

```

```

lr 6.500000e-09 reg 7.000000e+06 train accuracy: 0.415306 val accuracy: 0.421000
lr 6.500000e-09 reg 7.500000e+06 train accuracy: 0.418061 val accuracy: 0.419000
lr 7.000000e-09 reg 5.500000e+06 train accuracy: 0.416224 val accuracy: 0.417000
lr 7.000000e-09 reg 6.000000e+06 train accuracy: 0.414061 val accuracy: 0.404000
lr 7.000000e-09 reg 6.500000e+06 train accuracy: 0.411184 val accuracy: 0.397000
lr 7.000000e-09 reg 6.750000e+06 train accuracy: 0.416673 val accuracy: 0.415000
lr 7.000000e-09 reg 7.000000e+06 train accuracy: 0.420776 val accuracy: 0.422000
lr 7.000000e-09 reg 7.500000e+06 train accuracy: 0.413469 val accuracy: 0.407000
lr 7.500000e-09 reg 5.500000e+06 train accuracy: 0.421367 val accuracy: 0.419000
lr 7.500000e-09 reg 6.000000e+06 train accuracy: 0.414184 val accuracy: 0.402000
lr 7.500000e-09 reg 6.500000e+06 train accuracy: 0.414102 val accuracy: 0.408000
lr 7.500000e-09 reg 6.750000e+06 train accuracy: 0.414082 val accuracy: 0.415000
lr 7.500000e-09 reg 7.000000e+06 train accuracy: 0.420571 val accuracy: 0.426000
lr 7.500000e-09 reg 7.500000e+06 train accuracy: 0.410347 val accuracy: 0.424000
lr 8.000000e-09 reg 5.500000e+06 train accuracy: 0.418633 val accuracy: 0.413000
lr 8.000000e-09 reg 6.000000e+06 train accuracy: 0.411224 val accuracy: 0.415000
lr 8.000000e-09 reg 6.500000e+06 train accuracy: 0.413449 val accuracy: 0.403000
lr 8.000000e-09 reg 6.750000e+06 train accuracy: 0.408122 val accuracy: 0.401000
lr 8.000000e-09 reg 7.000000e+06 train accuracy: 0.420347 val accuracy: 0.442000
lr 8.000000e-09 reg 7.500000e+06 train accuracy: 0.414490 val accuracy: 0.397000
best validation accuracy achieved during cross-validation: 0.442000

```

```

[39]: # 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)

```

0.433

```

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

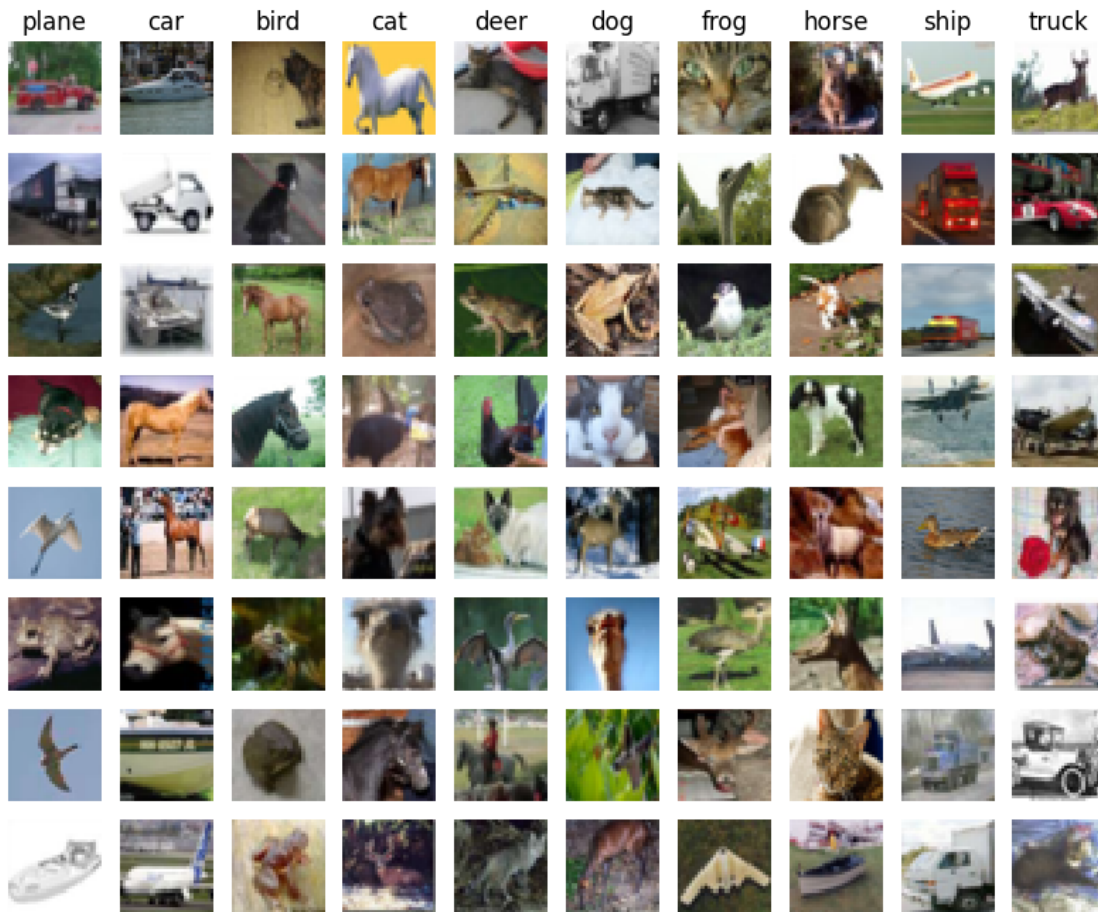
```

```

examples_per_class = 8
classes = ['plane', 'car', 'bird', 'cat', 'deer', 'dog', 'frog', 'horse', '
↳ '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()
```



1.3.1 Inline question 1:

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

When visualizing the misclassification results, we observe that the classifier often makes mistakes in ways that seem intuitive and are explainable based on visual and feature-level similarities between certain classes in the CIFAR-10 dataset. Let's break down the misclassifications for each class:

1. Planes (Predicted but Incorrect) Misclassified images often include "birds" and "ships." Reason: Planes and birds share similar sky-colored backgrounds or smooth outlines, while planes and ships can both be large objects in open environments. Does this make sense? Yes. Both "planes" and "birds" might have been confused due to feature overlaps in smooth gradients and edges. Similarly, "planes" and "ships" could have overlapping geometric shapes or colors in certain instances.
2. Cars (Predicted but Incorrect)

Misclassified images often include "trucks." Reason: Cars and trucks have very similar structural

features such as wheels, rectangular shapes, and colors. Does this make sense? Absolutely. The classifier may fail to differentiate subtle differences, such as the larger size or cargo area of a truck, especially since both share significant overlapping visual characteristics.

3. Birds (Predicted but Incorrect) Misclassified images include “planes” and “deer.” Reason: Birds and planes may share visual similarities in smooth curves, wings, and backgrounds with open skies. Similarly, “birds” and “deer” could be confused in cases where the texture and backgrounds (e.g., trees, grass) look similar. Does this make sense? Yes, particularly for bird-plane confusion, as both are seen in similar environmental contexts (sky backgrounds).
4. Cats (Predicted but Incorrect) Misclassified images include “dogs” and “horses.” Reason: Cats and dogs share similar textures (fur) and may have similar poses or backgrounds. Cats and horses could be confused when the background textures (e.g., grass or barns) dominate the feature extraction process. Does this make sense? Yes. Both cats and dogs are visually similar, and misclassifications between these two classes are common.
5. Deer (Predicted but Incorrect) Misclassified images include “horses” and “dogs.” Reason: Deer and horses often appear in similar natural settings (fields, forests) and have similar body structures. Dogs might be confused due to certain poses or textures, such as fur or background similarity. Does this make sense? Yes, since their body shapes and environments overlap.
6. Dogs (Predicted but Incorrect) Misclassified images include “cats” and “horses.” Reason: Dogs and cats share similar textures and features, while dogs and horses could be confused due to overlapping backgrounds and body orientations. Does this make sense? Yes, the feature overlap between furry animals or their environments contributes to this confusion.
7. Frogs (Predicted but Incorrect) Misclassified images include “cats” and “deer.” Reason: Frogs could be confused with animals found in natural settings (e.g., “deer”) due to similar environmental contexts, while “cats” might be due to poses or unclear feature extraction. Does this make sense? Yes, particularly in the case of misclassification with other natural or textured objects.
8. Horses (Predicted but Incorrect) Misclassified images include “deer” and “dogs.” Reason: Horses and deer share similar body shapes, while horses and dogs may be confused due to visual poses or background similarities. Does this make sense? Yes, because animals with similar shapes and environments are harder to distinguish.
9. Ships (Predicted but Incorrect) Misclassified images include “planes” and “cars.” Reason: Ships and planes share large smooth surfaces or open environment contexts (water vs. sky). Ships and cars might be confused due to rectangular structures or similar lighting. Does this make sense? Yes, since these classes share some common visual features.
10. Trucks (Predicted but Incorrect) Misclassified images include “cars.” Reason: Trucks and cars are visually similar, and their differences (e.g., size, cargo) may not be well captured by the features. Does this make sense? Yes, given that both classes share a significant feature overlap.

1.4 Neural Network on image features

Earlier in this assignment 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.

```
[44]: # 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, 163)
(49000, 162)

[47]: from cs6353.classifiers.neural_net import TwoLayerNet

#####
# TODO: Train a two-layer neural network on image features. You may want to #
# cross-validate various parameters as in previous sections. Store your best #
# model in the best_net variable. #
#####

# Define the network parameters
input_dim = X_train_feats.shape[1]
hidden_dim = 1000 # Increased hidden layer size
num_classes = 10
learning_rates = [1e-2, 1.5e-2] # Refined learning rates
regularization_strengths = [5e-4, 7e-4] # Refined regularization strengths
batch_size = 128 # Smaller batch size
num_iters = 20000 # Increased iterations

# Initialize variables to track the best network and validation accuracy
best_net = None
best_val_acc = -1
results = {}

# Perform cross-validation
for lr in learning_rates:
    for reg in regularization_strengths:
        print(f"Training with lr={lr}, reg={reg}")

        # Initialize a new TwoLayerNet
        net = TwoLayerNet(input_dim, hidden_dim, num_classes)
```

```

# Train the network
stats = net.train(
    X_train_feats, y_train,
    X_val_feats, y_val,
    num_iters=num_iters,
    batch_size=batch_size,
    learning_rate=lr,
    learning_rate_decay=0.98, # Slower decay
    reg=reg,
    verbose=True
)

# Evaluate the validation accuracy
val_acc = (net.predict(X_val_feats) == y_val).mean()
train_acc = (net.predict(X_train_feats) == y_train).mean()
print(f"Train Accuracy: {train_acc:.4f}, Validation Accuracy: {val_acc:.4f}")

# Store results
results[(lr, reg)] = (train_acc, val_acc)

# Update the best network if validation accuracy improves
if val_acc > best_val_acc:
    best_val_acc = val_acc
    best_net = net

print(f"Best validation accuracy: {best_val_acc:.4f}")

# Visualize results
import matplotlib.pyplot as plt
for (lr, reg), (train_acc, val_acc) in results.items():
    plt.scatter(reg, val_acc, label=f"LR: {lr}")
plt.xlabel("Regularization")
plt.ylabel("Validation Accuracy")
plt.legend()
plt.title("Validation Accuracy vs Regularization")
plt.show()

# Evaluate the best network on the test set
test_acc = (best_net.predict(X_test_feats) == y_test).mean()
print(f"Test accuracy: {test_acc:.4f}")

#####

```

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

```
Training with lr=0.01, reg=0.0005  
iteration 0 / 20000: loss 2.302586  
iteration 100 / 20000: loss 2.302877  
iteration 200 / 20000: loss 2.302793  
iteration 300 / 20000: loss 2.302779  
iteration 400 / 20000: loss 2.302004  
iteration 500 / 20000: loss 2.302591  
iteration 600 / 20000: loss 2.302275  
iteration 700 / 20000: loss 2.302148  
iteration 800 / 20000: loss 2.301900  
iteration 900 / 20000: loss 2.301194  
iteration 1000 / 20000: loss 2.301067  
iteration 1100 / 20000: loss 2.299259  
iteration 1200 / 20000: loss 2.296211  
iteration 1300 / 20000: loss 2.282430  
iteration 1400 / 20000: loss 2.277762  
iteration 1500 / 20000: loss 2.261511  
iteration 1600 / 20000: loss 2.205863  
iteration 1700 / 20000: loss 2.111349  
iteration 1800 / 20000: loss 2.115461  
iteration 1900 / 20000: loss 2.074275  
iteration 2000 / 20000: loss 2.031121  
iteration 2100 / 20000: loss 2.068694  
iteration 2200 / 20000: loss 1.902971  
iteration 2300 / 20000: loss 1.910992  
iteration 2400 / 20000: loss 1.876333  
iteration 2500 / 20000: loss 1.946103  
iteration 2600 / 20000: loss 1.769797  
iteration 2700 / 20000: loss 1.799132  
iteration 2800 / 20000: loss 1.816102  
iteration 2900 / 20000: loss 1.723902  
iteration 3000 / 20000: loss 1.775717  
iteration 3100 / 20000: loss 1.646138  
iteration 3200 / 20000: loss 1.677004  
iteration 3300 / 20000: loss 1.689550  
iteration 3400 / 20000: loss 1.532865  
iteration 3500 / 20000: loss 1.729575  
iteration 3600 / 20000: loss 1.520244  
iteration 3700 / 20000: loss 1.598823  
iteration 3800 / 20000: loss 1.569204  
iteration 3900 / 20000: loss 1.499020  
iteration 4000 / 20000: loss 1.425247  
iteration 4100 / 20000: loss 1.485542  
iteration 4200 / 20000: loss 1.541014  
iteration 4300 / 20000: loss 1.513914
```

iteration 4400 / 20000: loss 1.494849
iteration 4500 / 20000: loss 1.355756
iteration 4600 / 20000: loss 1.744727
iteration 4700 / 20000: loss 1.337560
iteration 4800 / 20000: loss 1.506974
iteration 4900 / 20000: loss 1.500545
iteration 5000 / 20000: loss 1.390050
iteration 5100 / 20000: loss 1.456574
iteration 5200 / 20000: loss 1.444039
iteration 5300 / 20000: loss 1.463102
iteration 5400 / 20000: loss 1.509929
iteration 5500 / 20000: loss 1.420199
iteration 5600 / 20000: loss 1.377510
iteration 5700 / 20000: loss 1.412090
iteration 5800 / 20000: loss 1.501068
iteration 5900 / 20000: loss 1.395192
iteration 6000 / 20000: loss 1.437366
iteration 6100 / 20000: loss 1.365567
iteration 6200 / 20000: loss 1.496696
iteration 6300 / 20000: loss 1.380322
iteration 6400 / 20000: loss 1.424010
iteration 6500 / 20000: loss 1.573699
iteration 6600 / 20000: loss 1.376561
iteration 6700 / 20000: loss 1.268353
iteration 6800 / 20000: loss 1.263999
iteration 6900 / 20000: loss 1.474415
iteration 7000 / 20000: loss 1.432725
iteration 7100 / 20000: loss 1.358184
iteration 7200 / 20000: loss 1.394003
iteration 7300 / 20000: loss 1.270509
iteration 7400 / 20000: loss 1.335636
iteration 7500 / 20000: loss 1.338023
iteration 7600 / 20000: loss 1.239429
iteration 7700 / 20000: loss 1.376051
iteration 7800 / 20000: loss 1.237840
iteration 7900 / 20000: loss 1.297426
iteration 8000 / 20000: loss 1.347393
iteration 8100 / 20000: loss 1.240248
iteration 8200 / 20000: loss 1.276859
iteration 8300 / 20000: loss 1.376133
iteration 8400 / 20000: loss 1.354137
iteration 8500 / 20000: loss 1.447655
iteration 8600 / 20000: loss 1.425295
iteration 8700 / 20000: loss 1.373301
iteration 8800 / 20000: loss 1.282949
iteration 8900 / 20000: loss 1.537773
iteration 9000 / 20000: loss 1.342258
iteration 9100 / 20000: loss 1.413378

iteration 9200 / 20000: loss 1.391302
iteration 9300 / 20000: loss 1.388107
iteration 9400 / 20000: loss 1.189785
iteration 9500 / 20000: loss 1.231568
iteration 9600 / 20000: loss 1.281281
iteration 9700 / 20000: loss 1.340635
iteration 9800 / 20000: loss 1.299581
iteration 9900 / 20000: loss 1.320434
iteration 10000 / 20000: loss 1.267466
iteration 10100 / 20000: loss 1.202317
iteration 10200 / 20000: loss 1.321557
iteration 10300 / 20000: loss 1.464262
iteration 10400 / 20000: loss 1.324497
iteration 10500 / 20000: loss 1.254374
iteration 10600 / 20000: loss 1.234084
iteration 10700 / 20000: loss 1.288922
iteration 10800 / 20000: loss 1.223008
iteration 10900 / 20000: loss 1.212183
iteration 11000 / 20000: loss 1.327920
iteration 11100 / 20000: loss 1.311601
iteration 11200 / 20000: loss 1.306980
iteration 11300 / 20000: loss 1.372966
iteration 11400 / 20000: loss 1.236802
iteration 11500 / 20000: loss 1.352063
iteration 11600 / 20000: loss 1.268097
iteration 11700 / 20000: loss 1.270722
iteration 11800 / 20000: loss 1.241943
iteration 11900 / 20000: loss 1.311495
iteration 12000 / 20000: loss 1.351640
iteration 12100 / 20000: loss 1.456546
iteration 12200 / 20000: loss 1.248257
iteration 12300 / 20000: loss 1.345518
iteration 12400 / 20000: loss 1.259316
iteration 12500 / 20000: loss 1.241382
iteration 12600 / 20000: loss 1.364527
iteration 12700 / 20000: loss 1.295311
iteration 12800 / 20000: loss 1.231973
iteration 12900 / 20000: loss 1.246397
iteration 13000 / 20000: loss 1.342696
iteration 13100 / 20000: loss 1.320967
iteration 13200 / 20000: loss 1.422688
iteration 13300 / 20000: loss 1.471579
iteration 13400 / 20000: loss 1.244174
iteration 13500 / 20000: loss 1.398022
iteration 13600 / 20000: loss 1.417994
iteration 13700 / 20000: loss 1.347984
iteration 13800 / 20000: loss 1.265552
iteration 13900 / 20000: loss 1.389293

iteration 14000 / 20000: loss 1.207926
iteration 14100 / 20000: loss 1.383923
iteration 14200 / 20000: loss 1.233348
iteration 14300 / 20000: loss 1.324884
iteration 14400 / 20000: loss 1.295858
iteration 14500 / 20000: loss 1.179937
iteration 14600 / 20000: loss 1.453376
iteration 14700 / 20000: loss 1.341707
iteration 14800 / 20000: loss 1.285085
iteration 14900 / 20000: loss 1.261751
iteration 15000 / 20000: loss 1.335763
iteration 15100 / 20000: loss 1.345407
iteration 15200 / 20000: loss 1.244688
iteration 15300 / 20000: loss 1.396919
iteration 15400 / 20000: loss 1.298364
iteration 15500 / 20000: loss 1.282356
iteration 15600 / 20000: loss 1.188346
iteration 15700 / 20000: loss 1.326204
iteration 15800 / 20000: loss 1.323872
iteration 15900 / 20000: loss 1.171512
iteration 16000 / 20000: loss 1.252871
iteration 16100 / 20000: loss 1.221542
iteration 16200 / 20000: loss 1.124139
iteration 16300 / 20000: loss 1.354113
iteration 16400 / 20000: loss 1.137652
iteration 16500 / 20000: loss 1.336225
iteration 16600 / 20000: loss 1.211457
iteration 16700 / 20000: loss 1.063550
iteration 16800 / 20000: loss 1.448144
iteration 16900 / 20000: loss 1.367130
iteration 17000 / 20000: loss 1.178388
iteration 17100 / 20000: loss 1.102255
iteration 17200 / 20000: loss 1.151641
iteration 17300 / 20000: loss 1.292607
iteration 17400 / 20000: loss 1.273912
iteration 17500 / 20000: loss 1.175307
iteration 17600 / 20000: loss 1.209970
iteration 17700 / 20000: loss 1.241190
iteration 17800 / 20000: loss 1.298561
iteration 17900 / 20000: loss 1.176022
iteration 18000 / 20000: loss 1.134487
iteration 18100 / 20000: loss 1.044421
iteration 18200 / 20000: loss 1.164002
iteration 18300 / 20000: loss 1.308007
iteration 18400 / 20000: loss 1.276127
iteration 18500 / 20000: loss 1.182080
iteration 18600 / 20000: loss 1.160922
iteration 18700 / 20000: loss 1.309334

iteration 18800 / 20000: loss 1.204596
iteration 18900 / 20000: loss 1.158716
iteration 19000 / 20000: loss 1.116842
iteration 19100 / 20000: loss 1.252600
iteration 19200 / 20000: loss 1.122161
iteration 19300 / 20000: loss 1.237605
iteration 19400 / 20000: loss 1.182360
iteration 19500 / 20000: loss 1.260472
iteration 19600 / 20000: loss 1.086249
iteration 19700 / 20000: loss 1.189047
iteration 19800 / 20000: loss 1.205147
iteration 19900 / 20000: loss 1.216344
Train Accuracy: 0.5801, Validation Accuracy: 0.5520
Training with lr=0.01, reg=0.0007
iteration 0 / 20000: loss 2.302586
iteration 100 / 20000: loss 2.302399
iteration 200 / 20000: loss 2.302233
iteration 300 / 20000: loss 2.302571
iteration 400 / 20000: loss 2.302717
iteration 500 / 20000: loss 2.301980
iteration 600 / 20000: loss 2.302481
iteration 700 / 20000: loss 2.302004
iteration 800 / 20000: loss 2.302041
iteration 900 / 20000: loss 2.302818
iteration 1000 / 20000: loss 2.300761
iteration 1100 / 20000: loss 2.299270
iteration 1200 / 20000: loss 2.296214
iteration 1300 / 20000: loss 2.289061
iteration 1400 / 20000: loss 2.278389
iteration 1500 / 20000: loss 2.260210
iteration 1600 / 20000: loss 2.224633
iteration 1700 / 20000: loss 2.188641
iteration 1800 / 20000: loss 2.175243
iteration 1900 / 20000: loss 2.086270
iteration 2000 / 20000: loss 2.093126
iteration 2100 / 20000: loss 2.029348
iteration 2200 / 20000: loss 1.977260
iteration 2300 / 20000: loss 1.914515
iteration 2400 / 20000: loss 1.874315
iteration 2500 / 20000: loss 1.787908
iteration 2600 / 20000: loss 1.728354
iteration 2700 / 20000: loss 1.704875
iteration 2800 / 20000: loss 1.839776
iteration 2900 / 20000: loss 1.874478
iteration 3000 / 20000: loss 1.657927
iteration 3100 / 20000: loss 1.673582
iteration 3200 / 20000: loss 1.657832
iteration 3300 / 20000: loss 1.606554

iteration 3400 / 20000: loss 1.624193
iteration 3500 / 20000: loss 1.621630
iteration 3600 / 20000: loss 1.555944
iteration 3700 / 20000: loss 1.624644
iteration 3800 / 20000: loss 1.542426
iteration 3900 / 20000: loss 1.558882
iteration 4000 / 20000: loss 1.561159
iteration 4100 / 20000: loss 1.559897
iteration 4200 / 20000: loss 1.534701
iteration 4300 / 20000: loss 1.527627
iteration 4400 / 20000: loss 1.439716
iteration 4500 / 20000: loss 1.435057
iteration 4600 / 20000: loss 1.447378
iteration 4700 / 20000: loss 1.472251
iteration 4800 / 20000: loss 1.390824
iteration 4900 / 20000: loss 1.401612
iteration 5000 / 20000: loss 1.361573
iteration 5100 / 20000: loss 1.406252
iteration 5200 / 20000: loss 1.447957
iteration 5300 / 20000: loss 1.400985
iteration 5400 / 20000: loss 1.489649
iteration 5500 / 20000: loss 1.343900
iteration 5600 / 20000: loss 1.504328
iteration 5700 / 20000: loss 1.478178
iteration 5800 / 20000: loss 1.447338
iteration 5900 / 20000: loss 1.378533
iteration 6000 / 20000: loss 1.508060
iteration 6100 / 20000: loss 1.528821
iteration 6200 / 20000: loss 1.463892
iteration 6300 / 20000: loss 1.329574
iteration 6400 / 20000: loss 1.418990
iteration 6500 / 20000: loss 1.421722
iteration 6600 / 20000: loss 1.385446
iteration 6700 / 20000: loss 1.341427
iteration 6800 / 20000: loss 1.379701
iteration 6900 / 20000: loss 1.377010
iteration 7000 / 20000: loss 1.567953
iteration 7100 / 20000: loss 1.537761
iteration 7200 / 20000: loss 1.404748
iteration 7300 / 20000: loss 1.370100
iteration 7400 / 20000: loss 1.170629
iteration 7500 / 20000: loss 1.365144
iteration 7600 / 20000: loss 1.261544
iteration 7700 / 20000: loss 1.334299
iteration 7800 / 20000: loss 1.280111
iteration 7900 / 20000: loss 1.391465
iteration 8000 / 20000: loss 1.354720
iteration 8100 / 20000: loss 1.299416

iteration 8200 / 20000: loss 1.262918
iteration 8300 / 20000: loss 1.364691
iteration 8400 / 20000: loss 1.300900
iteration 8500 / 20000: loss 1.216483
iteration 8600 / 20000: loss 1.332017
iteration 8700 / 20000: loss 1.400743
iteration 8800 / 20000: loss 1.236485
iteration 8900 / 20000: loss 1.152038
iteration 9000 / 20000: loss 1.435840
iteration 9100 / 20000: loss 1.397841
iteration 9200 / 20000: loss 1.435604
iteration 9300 / 20000: loss 1.404873
iteration 9400 / 20000: loss 1.359492
iteration 9500 / 20000: loss 1.456144
iteration 9600 / 20000: loss 1.393975
iteration 9700 / 20000: loss 1.355936
iteration 9800 / 20000: loss 1.466543
iteration 9900 / 20000: loss 1.523976
iteration 10000 / 20000: loss 1.242960
iteration 10100 / 20000: loss 1.288252
iteration 10200 / 20000: loss 1.370881
iteration 10300 / 20000: loss 1.383931
iteration 10400 / 20000: loss 1.451934
iteration 10500 / 20000: loss 1.406741
iteration 10600 / 20000: loss 1.184916
iteration 10700 / 20000: loss 1.436231
iteration 10800 / 20000: loss 1.436004
iteration 10900 / 20000: loss 1.440168
iteration 11000 / 20000: loss 1.339496
iteration 11100 / 20000: loss 1.457210
iteration 11200 / 20000: loss 1.307410
iteration 11300 / 20000: loss 1.266746
iteration 11400 / 20000: loss 1.448131
iteration 11500 / 20000: loss 1.376884
iteration 11600 / 20000: loss 1.422934
iteration 11700 / 20000: loss 1.376527
iteration 11800 / 20000: loss 1.373338
iteration 11900 / 20000: loss 1.251379
iteration 12000 / 20000: loss 1.329416
iteration 12100 / 20000: loss 1.387157
iteration 12200 / 20000: loss 1.320790
iteration 12300 / 20000: loss 1.404071
iteration 12400 / 20000: loss 1.435431
iteration 12500 / 20000: loss 1.364563
iteration 12600 / 20000: loss 1.280678
iteration 12700 / 20000: loss 1.295939
iteration 12800 / 20000: loss 1.199886
iteration 12900 / 20000: loss 1.338732

iteration 13000 / 20000: loss 1.355340
iteration 13100 / 20000: loss 1.454547
iteration 13200 / 20000: loss 1.402656
iteration 13300 / 20000: loss 1.210617
iteration 13400 / 20000: loss 1.231551
iteration 13500 / 20000: loss 1.424312
iteration 13600 / 20000: loss 1.296830
iteration 13700 / 20000: loss 1.350418
iteration 13800 / 20000: loss 1.526286
iteration 13900 / 20000: loss 1.291112
iteration 14000 / 20000: loss 1.285395
iteration 14100 / 20000: loss 1.321095
iteration 14200 / 20000: loss 1.449241
iteration 14300 / 20000: loss 1.382249
iteration 14400 / 20000: loss 1.178542
iteration 14500 / 20000: loss 1.266384
iteration 14600 / 20000: loss 1.431118
iteration 14700 / 20000: loss 1.170835
iteration 14800 / 20000: loss 1.369079
iteration 14900 / 20000: loss 1.312762
iteration 15000 / 20000: loss 1.216363
iteration 15100 / 20000: loss 1.295097
iteration 15200 / 20000: loss 1.303523
iteration 15300 / 20000: loss 1.186387
iteration 15400 / 20000: loss 1.262835
iteration 15500 / 20000: loss 1.315316
iteration 15600 / 20000: loss 1.235544
iteration 15700 / 20000: loss 1.245422
iteration 15800 / 20000: loss 1.210712
iteration 15900 / 20000: loss 1.185197
iteration 16000 / 20000: loss 1.253143
iteration 16100 / 20000: loss 1.182895
iteration 16200 / 20000: loss 1.337762
iteration 16300 / 20000: loss 1.222014
iteration 16400 / 20000: loss 1.380888
iteration 16500 / 20000: loss 1.081877
iteration 16600 / 20000: loss 1.199061
iteration 16700 / 20000: loss 1.239168
iteration 16800 / 20000: loss 1.256552
iteration 16900 / 20000: loss 1.338216
iteration 17000 / 20000: loss 1.128321
iteration 17100 / 20000: loss 1.225264
iteration 17200 / 20000: loss 1.266514
iteration 17300 / 20000: loss 1.063029
iteration 17400 / 20000: loss 1.158190
iteration 17500 / 20000: loss 1.246537
iteration 17600 / 20000: loss 1.413764
iteration 17700 / 20000: loss 1.530519

iteration 17800 / 20000: loss 1.381575
iteration 17900 / 20000: loss 1.248079
iteration 18000 / 20000: loss 1.213168
iteration 18100 / 20000: loss 1.310261
iteration 18200 / 20000: loss 1.346108
iteration 18300 / 20000: loss 1.356765
iteration 18400 / 20000: loss 1.275918
iteration 18500 / 20000: loss 1.273273
iteration 18600 / 20000: loss 1.248050
iteration 18700 / 20000: loss 1.323000
iteration 18800 / 20000: loss 1.207172
iteration 18900 / 20000: loss 1.374435
iteration 19000 / 20000: loss 1.270342
iteration 19100 / 20000: loss 1.295519
iteration 19200 / 20000: loss 1.166442
iteration 19300 / 20000: loss 1.108583
iteration 19400 / 20000: loss 1.326018
iteration 19500 / 20000: loss 1.131545
iteration 19600 / 20000: loss 1.271477
iteration 19700 / 20000: loss 1.159195
iteration 19800 / 20000: loss 1.238827
iteration 19900 / 20000: loss 1.274817
Train Accuracy: 0.5781, Validation Accuracy: 0.5510
Training with lr=0.015, reg=0.0005
iteration 0 / 20000: loss 2.302586
iteration 100 / 20000: loss 2.302397
iteration 200 / 20000: loss 2.302190
iteration 300 / 20000: loss 2.302417
iteration 400 / 20000: loss 2.302446
iteration 500 / 20000: loss 2.301955
iteration 600 / 20000: loss 2.302873
iteration 700 / 20000: loss 2.300796
iteration 800 / 20000: loss 2.294384
iteration 900 / 20000: loss 2.289182
iteration 1000 / 20000: loss 2.262549
iteration 1100 / 20000: loss 2.198189
iteration 1200 / 20000: loss 2.164200
iteration 1300 / 20000: loss 2.089513
iteration 1400 / 20000: loss 1.985465
iteration 1500 / 20000: loss 1.957777
iteration 1600 / 20000: loss 1.830499
iteration 1700 / 20000: loss 1.830615
iteration 1800 / 20000: loss 1.729500
iteration 1900 / 20000: loss 1.677744
iteration 2000 / 20000: loss 1.774728
iteration 2100 / 20000: loss 1.709982
iteration 2200 / 20000: loss 1.719783
iteration 2300 / 20000: loss 1.657907

iteration 2400 / 20000: loss 1.624639
iteration 2500 / 20000: loss 1.588120
iteration 2600 / 20000: loss 1.516926
iteration 2700 / 20000: loss 1.604801
iteration 2800 / 20000: loss 1.558550
iteration 2900 / 20000: loss 1.535209
iteration 3000 / 20000: loss 1.434951
iteration 3100 / 20000: loss 1.453669
iteration 3200 / 20000: loss 1.495363
iteration 3300 / 20000: loss 1.352989
iteration 3400 / 20000: loss 1.376749
iteration 3500 / 20000: loss 1.364751
iteration 3600 / 20000: loss 1.476326
iteration 3700 / 20000: loss 1.381205
iteration 3800 / 20000: loss 1.422982
iteration 3900 / 20000: loss 1.333360
iteration 4000 / 20000: loss 1.401653
iteration 4100 / 20000: loss 1.516900
iteration 4200 / 20000: loss 1.433989
iteration 4300 / 20000: loss 1.318402
iteration 4400 / 20000: loss 1.508055
iteration 4500 / 20000: loss 1.382565
iteration 4600 / 20000: loss 1.293161
iteration 4700 / 20000: loss 1.402704
iteration 4800 / 20000: loss 1.332578
iteration 4900 / 20000: loss 1.210731
iteration 5000 / 20000: loss 1.364123
iteration 5100 / 20000: loss 1.358213
iteration 5200 / 20000: loss 1.205900
iteration 5300 / 20000: loss 1.149733
iteration 5400 / 20000: loss 1.391952
iteration 5500 / 20000: loss 1.280056
iteration 5600 / 20000: loss 1.409690
iteration 5700 / 20000: loss 1.494858
iteration 5800 / 20000: loss 1.208175
iteration 5900 / 20000: loss 1.369338
iteration 6000 / 20000: loss 1.481380
iteration 6100 / 20000: loss 1.305145
iteration 6200 / 20000: loss 1.223392
iteration 6300 / 20000: loss 1.261191
iteration 6400 / 20000: loss 1.397406
iteration 6500 / 20000: loss 1.375074
iteration 6600 / 20000: loss 1.299986
iteration 6700 / 20000: loss 1.405979
iteration 6800 / 20000: loss 1.293687
iteration 6900 / 20000: loss 1.359630
iteration 7000 / 20000: loss 1.409109
iteration 7100 / 20000: loss 1.154508

iteration 7200 / 20000: loss 1.456790
iteration 7300 / 20000: loss 1.452587
iteration 7400 / 20000: loss 1.419160
iteration 7500 / 20000: loss 1.378206
iteration 7600 / 20000: loss 1.349416
iteration 7700 / 20000: loss 1.410145
iteration 7800 / 20000: loss 1.201206
iteration 7900 / 20000: loss 1.314171
iteration 8000 / 20000: loss 1.251077
iteration 8100 / 20000: loss 1.151624
iteration 8200 / 20000: loss 1.315179
iteration 8300 / 20000: loss 1.449002
iteration 8400 / 20000: loss 1.221367
iteration 8500 / 20000: loss 1.141035
iteration 8600 / 20000: loss 1.364330
iteration 8700 / 20000: loss 1.353906
iteration 8800 / 20000: loss 1.535753
iteration 8900 / 20000: loss 1.349654
iteration 9000 / 20000: loss 1.230981
iteration 9100 / 20000: loss 1.439509
iteration 9200 / 20000: loss 1.350026
iteration 9300 / 20000: loss 1.009161
iteration 9400 / 20000: loss 1.235260
iteration 9500 / 20000: loss 1.370400
iteration 9600 / 20000: loss 1.452217
iteration 9700 / 20000: loss 1.283243
iteration 9800 / 20000: loss 1.247011
iteration 9900 / 20000: loss 1.235243
iteration 10000 / 20000: loss 1.271533
iteration 10100 / 20000: loss 1.236884
iteration 10200 / 20000: loss 1.378756
iteration 10300 / 20000: loss 1.273084
iteration 10400 / 20000: loss 1.144016
iteration 10500 / 20000: loss 1.256614
iteration 10600 / 20000: loss 1.291016
iteration 10700 / 20000: loss 1.252823
iteration 10800 / 20000: loss 1.322135
iteration 10900 / 20000: loss 1.307768
iteration 11000 / 20000: loss 1.327561
iteration 11100 / 20000: loss 1.147877
iteration 11200 / 20000: loss 1.327926
iteration 11300 / 20000: loss 1.252852
iteration 11400 / 20000: loss 1.242297
iteration 11500 / 20000: loss 1.285034
iteration 11600 / 20000: loss 1.198949
iteration 11700 / 20000: loss 1.281183
iteration 11800 / 20000: loss 1.308514
iteration 11900 / 20000: loss 1.111692

iteration 12000 / 20000: loss 1.271157
iteration 12100 / 20000: loss 1.196352
iteration 12200 / 20000: loss 1.215995
iteration 12300 / 20000: loss 1.098887
iteration 12400 / 20000: loss 1.211707
iteration 12500 / 20000: loss 1.270603
iteration 12600 / 20000: loss 1.206647
iteration 12700 / 20000: loss 1.228921
iteration 12800 / 20000: loss 1.167935
iteration 12900 / 20000: loss 1.143618
iteration 13000 / 20000: loss 1.241825
iteration 13100 / 20000: loss 1.281344
iteration 13200 / 20000: loss 1.374205
iteration 13300 / 20000: loss 1.087596
iteration 13400 / 20000: loss 1.222384
iteration 13500 / 20000: loss 1.287582
iteration 13600 / 20000: loss 1.172138
iteration 13700 / 20000: loss 1.186201
iteration 13800 / 20000: loss 1.236490
iteration 13900 / 20000: loss 1.000730
iteration 14000 / 20000: loss 1.246213
iteration 14100 / 20000: loss 1.089157
iteration 14200 / 20000: loss 1.168032
iteration 14300 / 20000: loss 1.208214
iteration 14400 / 20000: loss 1.155140
iteration 14500 / 20000: loss 1.061206
iteration 14600 / 20000: loss 1.040398
iteration 14700 / 20000: loss 1.103554
iteration 14800 / 20000: loss 1.188366
iteration 14900 / 20000: loss 1.245495
iteration 15000 / 20000: loss 1.218298
iteration 15100 / 20000: loss 1.369550
iteration 15200 / 20000: loss 1.150045
iteration 15300 / 20000: loss 1.050313
iteration 15400 / 20000: loss 1.242686
iteration 15500 / 20000: loss 1.304246
iteration 15600 / 20000: loss 1.213802
iteration 15700 / 20000: loss 1.295404
iteration 15800 / 20000: loss 1.244778
iteration 15900 / 20000: loss 1.236140
iteration 16000 / 20000: loss 1.150483
iteration 16100 / 20000: loss 1.166302
iteration 16200 / 20000: loss 1.143307
iteration 16300 / 20000: loss 1.311616
iteration 16400 / 20000: loss 1.290035
iteration 16500 / 20000: loss 1.162030
iteration 16600 / 20000: loss 1.129183
iteration 16700 / 20000: loss 1.070122

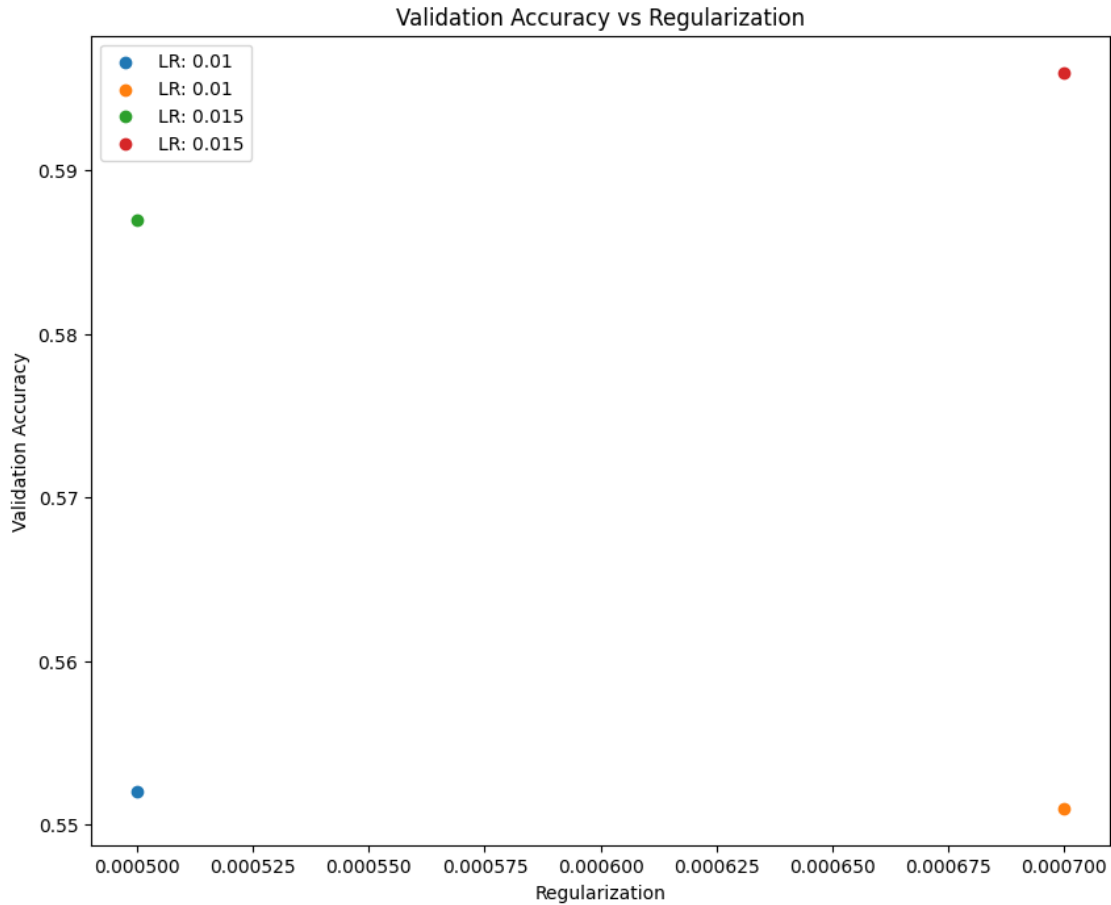
```
iteration 16800 / 20000: loss 1.084502
iteration 16900 / 20000: loss 1.246781
iteration 17000 / 20000: loss 1.170089
iteration 17100 / 20000: loss 0.934783
iteration 17200 / 20000: loss 1.102442
iteration 17300 / 20000: loss 1.367188
iteration 17400 / 20000: loss 1.258441
iteration 17500 / 20000: loss 1.076288
iteration 17600 / 20000: loss 1.196601
iteration 17700 / 20000: loss 1.262888
iteration 17800 / 20000: loss 1.127078
iteration 17900 / 20000: loss 1.008874
iteration 18000 / 20000: loss 0.957612
iteration 18100 / 20000: loss 1.165867
iteration 18200 / 20000: loss 1.079597
iteration 18300 / 20000: loss 1.132489
iteration 18400 / 20000: loss 1.130830
iteration 18500 / 20000: loss 1.161295
iteration 18600 / 20000: loss 1.144033
iteration 18700 / 20000: loss 1.170039
iteration 18800 / 20000: loss 1.147364
iteration 18900 / 20000: loss 1.089646
iteration 19000 / 20000: loss 1.017884
iteration 19100 / 20000: loss 1.125586
iteration 19200 / 20000: loss 1.131223
iteration 19300 / 20000: loss 1.095486
iteration 19400 / 20000: loss 1.081808
iteration 19500 / 20000: loss 1.160927
iteration 19600 / 20000: loss 1.124902
iteration 19700 / 20000: loss 1.017023
iteration 19800 / 20000: loss 0.903453
iteration 19900 / 20000: loss 1.170195
Train Accuracy: 0.6266, Validation Accuracy: 0.5870
Training with lr=0.015, reg=0.0007
iteration 0 / 20000: loss 2.302586
iteration 100 / 20000: loss 2.303279
iteration 200 / 20000: loss 2.302412
iteration 300 / 20000: loss 2.302412
iteration 400 / 20000: loss 2.302882
iteration 500 / 20000: loss 2.302107
iteration 600 / 20000: loss 2.301538
iteration 700 / 20000: loss 2.300439
iteration 800 / 20000: loss 2.298462
iteration 900 / 20000: loss 2.289036
iteration 1000 / 20000: loss 2.259488
iteration 1100 / 20000: loss 2.209197
iteration 1200 / 20000: loss 2.125526
iteration 1300 / 20000: loss 2.051307
```


iteration 1400 / 20000: loss 2.039304
iteration 1500 / 20000: loss 2.005091
iteration 1600 / 20000: loss 1.912901
iteration 1700 / 20000: loss 1.869512
iteration 1800 / 20000: loss 1.708358
iteration 1900 / 20000: loss 1.833543
iteration 2000 / 20000: loss 1.684746
iteration 2100 / 20000: loss 1.773412
iteration 2200 / 20000: loss 1.622297
iteration 2300 / 20000: loss 1.549909
iteration 2400 / 20000: loss 1.609137
iteration 2500 / 20000: loss 1.604916
iteration 2600 / 20000: loss 1.496195
iteration 2700 / 20000: loss 1.544440
iteration 2800 / 20000: loss 1.527840
iteration 2900 / 20000: loss 1.492066
iteration 3000 / 20000: loss 1.583535
iteration 3100 / 20000: loss 1.501959
iteration 3200 / 20000: loss 1.541745
iteration 3300 / 20000: loss 1.488035
iteration 3400 / 20000: loss 1.458673
iteration 3500 / 20000: loss 1.688922
iteration 3600 / 20000: loss 1.347733
iteration 3700 / 20000: loss 1.382839
iteration 3800 / 20000: loss 1.427605
iteration 3900 / 20000: loss 1.455491
iteration 4000 / 20000: loss 1.328915
iteration 4100 / 20000: loss 1.370375
iteration 4200 / 20000: loss 1.457915
iteration 4300 / 20000: loss 1.425020
iteration 4400 / 20000: loss 1.369112
iteration 4500 / 20000: loss 1.484565
iteration 4600 / 20000: loss 1.348065
iteration 4700 / 20000: loss 1.310663
iteration 4800 / 20000: loss 1.380387
iteration 4900 / 20000: loss 1.410092
iteration 5000 / 20000: loss 1.336778
iteration 5100 / 20000: loss 1.436972
iteration 5200 / 20000: loss 1.298105
iteration 5300 / 20000: loss 1.420493
iteration 5400 / 20000: loss 1.237006
iteration 5500 / 20000: loss 1.428327
iteration 5600 / 20000: loss 1.405148
iteration 5700 / 20000: loss 1.402200
iteration 5800 / 20000: loss 1.493314
iteration 5900 / 20000: loss 1.234930
iteration 6000 / 20000: loss 1.259428
iteration 6100 / 20000: loss 1.239057

iteration 6200 / 20000: loss 1.340191
iteration 6300 / 20000: loss 1.348174
iteration 6400 / 20000: loss 1.193090
iteration 6500 / 20000: loss 1.385834
iteration 6600 / 20000: loss 1.389880
iteration 6700 / 20000: loss 1.288581
iteration 6800 / 20000: loss 1.187235
iteration 6900 / 20000: loss 1.382108
iteration 7000 / 20000: loss 1.453800
iteration 7100 / 20000: loss 1.411874
iteration 7200 / 20000: loss 1.382153
iteration 7300 / 20000: loss 1.417335
iteration 7400 / 20000: loss 1.376620
iteration 7500 / 20000: loss 1.397753
iteration 7600 / 20000: loss 1.477669
iteration 7700 / 20000: loss 1.318552
iteration 7800 / 20000: loss 1.327694
iteration 7900 / 20000: loss 1.212448
iteration 8000 / 20000: loss 1.270231
iteration 8100 / 20000: loss 1.254725
iteration 8200 / 20000: loss 1.375096
iteration 8300 / 20000: loss 1.308143
iteration 8400 / 20000: loss 1.340770
iteration 8500 / 20000: loss 1.371985
iteration 8600 / 20000: loss 1.188812
iteration 8700 / 20000: loss 1.204675
iteration 8800 / 20000: loss 1.404958
iteration 8900 / 20000: loss 1.413928
iteration 9000 / 20000: loss 1.159376
iteration 9100 / 20000: loss 1.336297
iteration 9200 / 20000: loss 1.327675
iteration 9300 / 20000: loss 1.280770
iteration 9400 / 20000: loss 1.451727
iteration 9500 / 20000: loss 1.375027
iteration 9600 / 20000: loss 1.392967
iteration 9700 / 20000: loss 1.182630
iteration 9800 / 20000: loss 1.232846
iteration 9900 / 20000: loss 1.419970
iteration 10000 / 20000: loss 1.248781
iteration 10100 / 20000: loss 1.228360
iteration 10200 / 20000: loss 1.206881
iteration 10300 / 20000: loss 1.487987
iteration 10400 / 20000: loss 1.175004
iteration 10500 / 20000: loss 1.368663
iteration 10600 / 20000: loss 1.285220
iteration 10700 / 20000: loss 1.279043
iteration 10800 / 20000: loss 1.076202
iteration 10900 / 20000: loss 1.253518

iteration 11000 / 20000: loss 1.187973
iteration 11100 / 20000: loss 1.415180
iteration 11200 / 20000: loss 1.251374
iteration 11300 / 20000: loss 1.290086
iteration 11400 / 20000: loss 1.265886
iteration 11500 / 20000: loss 1.251106
iteration 11600 / 20000: loss 1.239297
iteration 11700 / 20000: loss 1.197685
iteration 11800 / 20000: loss 1.312958
iteration 11900 / 20000: loss 1.209652
iteration 12000 / 20000: loss 1.279075
iteration 12100 / 20000: loss 1.244994
iteration 12200 / 20000: loss 1.303716
iteration 12300 / 20000: loss 1.289915
iteration 12400 / 20000: loss 1.248302
iteration 12500 / 20000: loss 1.214508
iteration 12600 / 20000: loss 1.244691
iteration 12700 / 20000: loss 1.190263
iteration 12800 / 20000: loss 1.246803
iteration 12900 / 20000: loss 1.216723
iteration 13000 / 20000: loss 1.273217
iteration 13100 / 20000: loss 1.145306
iteration 13200 / 20000: loss 1.371341
iteration 13300 / 20000: loss 1.148069
iteration 13400 / 20000: loss 1.355968
iteration 13500 / 20000: loss 1.119309
iteration 13600 / 20000: loss 1.236241
iteration 13700 / 20000: loss 1.177605
iteration 13800 / 20000: loss 1.077647
iteration 13900 / 20000: loss 1.177237
iteration 14000 / 20000: loss 1.140199
iteration 14100 / 20000: loss 1.290002
iteration 14200 / 20000: loss 1.196643
iteration 14300 / 20000: loss 1.311520
iteration 14400 / 20000: loss 1.258175
iteration 14500 / 20000: loss 1.189738
iteration 14600 / 20000: loss 1.217078
iteration 14700 / 20000: loss 1.161422
iteration 14800 / 20000: loss 1.182512
iteration 14900 / 20000: loss 1.327140
iteration 15000 / 20000: loss 1.222188
iteration 15100 / 20000: loss 1.150091
iteration 15200 / 20000: loss 1.234221
iteration 15300 / 20000: loss 1.039930
iteration 15400 / 20000: loss 1.039262
iteration 15500 / 20000: loss 1.240504
iteration 15600 / 20000: loss 1.252768
iteration 15700 / 20000: loss 1.092302

iteration 15800 / 20000: loss 1.160601
iteration 15900 / 20000: loss 1.356008
iteration 16000 / 20000: loss 1.263984
iteration 16100 / 20000: loss 1.335170
iteration 16200 / 20000: loss 1.236433
iteration 16300 / 20000: loss 1.077276
iteration 16400 / 20000: loss 1.175924
iteration 16500 / 20000: loss 1.260077
iteration 16600 / 20000: loss 1.107919
iteration 16700 / 20000: loss 1.119303
iteration 16800 / 20000: loss 1.252540
iteration 16900 / 20000: loss 1.299406
iteration 17000 / 20000: loss 1.151808
iteration 17100 / 20000: loss 1.191842
iteration 17200 / 20000: loss 1.300194
iteration 17300 / 20000: loss 1.126133
iteration 17400 / 20000: loss 1.211164
iteration 17500 / 20000: loss 1.184070
iteration 17600 / 20000: loss 1.245069
iteration 17700 / 20000: loss 1.151482
iteration 17800 / 20000: loss 1.036555
iteration 17900 / 20000: loss 1.100701
iteration 18000 / 20000: loss 1.137958
iteration 18100 / 20000: loss 0.972746
iteration 18200 / 20000: loss 1.230967
iteration 18300 / 20000: loss 1.271519
iteration 18400 / 20000: loss 1.068712
iteration 18500 / 20000: loss 1.167642
iteration 18600 / 20000: loss 1.164594
iteration 18700 / 20000: loss 1.210770
iteration 18800 / 20000: loss 1.170967
iteration 18900 / 20000: loss 1.059709
iteration 19000 / 20000: loss 1.127446
iteration 19100 / 20000: loss 1.063460
iteration 19200 / 20000: loss 1.135209
iteration 19300 / 20000: loss 1.111474
iteration 19400 / 20000: loss 1.237687
iteration 19500 / 20000: loss 1.073277
iteration 19600 / 20000: loss 1.162659
iteration 19700 / 20000: loss 1.060825
iteration 19800 / 20000: loss 1.155116
iteration 19900 / 20000: loss 1.164936
Train Accuracy: 0.6237, Validation Accuracy: 0.5960
Best validation accuracy: 0.5960



Test accuracy: 0.5570

[48]: *# 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)
```

0.557

[51]: `!pip install nbconvert`
`!apt-get install texlive-xetex texlive-fonts-recommended`
`↪texlive-generic-recommended`

Requirement already satisfied: nbconvert in /usr/local/lib/python3.10/dist-packages (7.7.4)

Requirement already satisfied: beautifulsoup4 in /usr/local/lib/python3.10/dist-packages (from nbconvert) (4.12.2)

Requirement already satisfied: bleach!=5.0.0 in /usr/local/lib/python3.10/dist-packages (from nbconvert) (6.0.0)

Requirement already satisfied: defusedxml in /usr/local/lib/python3.10/dist-packages (from nbconvert) (0.7.1)

Requirement already satisfied: Jinja2>=3.0 in /usr/local/lib/python3.10/dist-packages (from nbconvert) (3.1.2)

Requirement already satisfied: jupyter-core>=4.7 in /usr/local/lib/python3.10/dist-packages (from nbconvert) (5.3.1)

Requirement already satisfied: jupyterlab-pygments in /usr/local/lib/python3.10/dist-packages (from nbconvert) (0.2.2)

Requirement already satisfied: MarkupSafe>=2.0 in /usr/local/lib/python3.10/dist-packages (from nbconvert) (2.1.3)

Requirement already satisfied: mistune<4,>=2.0.3 in /usr/local/lib/python3.10/dist-packages (from nbconvert) (3.0.1)

Requirement already satisfied: nbclient>=0.5.0 in /usr/local/lib/python3.10/dist-packages (from nbconvert) (0.8.0)

Requirement already satisfied: nbformat>=5.7 in /usr/local/lib/python3.10/dist-packages (from nbconvert) (5.9.2)

Requirement already satisfied: packaging in /usr/local/lib/python3.10/dist-packages (from nbconvert) (23.1)

Requirement already satisfied: pandocfilters>=1.4.1 in /usr/local/lib/python3.10/dist-packages (from nbconvert) (1.5.0)

Requirement already satisfied: pygments>=2.4.1 in /usr/local/lib/python3.10/dist-packages (from nbconvert) (2.16.1)

Requirement already satisfied: tinycss2 in /usr/local/lib/python3.10/dist-packages (from nbconvert) (1.2.1)

Requirement already satisfied: traitlets>=5.1 in /usr/local/lib/python3.10/dist-packages (from nbconvert) (5.9.0)

Requirement already satisfied: six>=1.9.0 in /usr/local/lib/python3.10/dist-packages (from bleach!=5.0.0->nbconvert) (1.16.0)

Requirement already satisfied: webencodings in /usr/local/lib/python3.10/dist-packages (from bleach!=5.0.0->nbconvert) (0.5.1)

Requirement already satisfied: platformdirs>=2.5 in /usr/local/lib/python3.10/dist-packages (from jupyter-core>=4.7->nbconvert) (3.10.0)

Requirement already satisfied: jupyter-client>=6.1.12 in /usr/local/lib/python3.10/dist-packages (from nbclient>=0.5.0->nbconvert) (7.4.9)

Requirement already satisfied: fastjsonschema in /usr/local/lib/python3.10/dist-packages (from nbformat>=5.7->nbconvert) (2.18.0)

Requirement already satisfied: jsonschema>=2.6 in /usr/local/lib/python3.10/dist-packages (from nbformat>=5.7->nbconvert) (4.19.0)

Requirement already satisfied: soupsieve>1.2 in /usr/local/lib/python3.10/dist-packages (from BeautifulSoup4->nbconvert) (2.4.1)

Requirement already satisfied: attrs>=22.2.0 in /usr/local/lib/python3.10/dist-packages (from jsonschema>=2.6->nbformat>=5.7->nbconvert) (23.1.0)

Requirement already satisfied: jsonschema-specifications>=2023.03.6 in /usr/local/lib/python3.10/dist-packages (from jsonschema>=2.6->nbformat>=5.7->nbconvert) (2023.7.1)

Requirement already satisfied: referencing>=0.28.4 in

```

/usr/local/lib/python3.10/dist-packages (from
jsonschema>=2.6->nbformat>=5.7->nbconvert) (0.30.2)
Requirement already satisfied: rpds-py>=0.7.1 in /usr/local/lib/python3.10/dist-
packages (from jsonschema>=2.6->nbformat>=5.7->nbconvert) (0.9.2)
Requirement already satisfied: entrypoints in /usr/local/lib/python3.10/dist-
packages (from jupyter-client>=6.1.12->nbclient>=0.5.0->nbconvert) (0.4)
Requirement already satisfied: nest-asyncio>=1.5.4 in
/usr/local/lib/python3.10/dist-packages (from jupyter-
client>=6.1.12->nbclient>=0.5.0->nbconvert) (1.5.7)
Requirement already satisfied: python-dateutil>=2.8.2 in
/usr/local/lib/python3.10/dist-packages (from jupyter-
client>=6.1.12->nbclient>=0.5.0->nbconvert) (2.8.2)
Requirement already satisfied: pyzmq>=23.0 in /usr/local/lib/python3.10/dist-
packages (from jupyter-client>=6.1.12->nbclient>=0.5.0->nbconvert) (24.0.1)
Requirement already satisfied: tornado>=6.2 in /usr/local/lib/python3.10/dist-
packages (from jupyter-client>=6.1.12->nbclient>=0.5.0->nbconvert) (6.3.2)
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
E: Unable to locate package texlive-generic-recommended

```

```
[56]: from google.colab import files
```

```
!jupyter nbconvert features.ipynb --to html
```

```

[NbConvertApp] Converting notebook features.ipynb to html
[NbConvertApp] WARNING | Alternative text is missing on 2 image(s).
[NbConvertApp] Writing 955928 bytes to features.html

```