In [ ]:

```python
# 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/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/$FOLDERNAME/cs6353/datasets/
!bash get_datasets.sh
%cd /content/drive/My\ Drive/$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/assignment2/cs6353/datasets
--2024-09-29 20:36:13--  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'

cifar-10-python.tar 100%[===================>] 162.60M  16.0MB/s    in 11s

2024-09-29 20:36:25 (14.3 MB/s) - 'cifar-10-python.tar.gz' saved [170498071/17049807
1]

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/assignment2
Requirement already satisfied: anyio==3.7.1 in /usr/local/lib/python3.10/dist-package
s (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//colab_
requirements.txt (line 1)) (3.7.1)
Collecting appnope==0.1.3 (from -r /content/drive/My Drive/CS6353/Assignments/assignm
ent2/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/assignment
2//colab_requirements.txt (line 3)) (23.1.0)
Requirement already satisfied: argon2-cffi-bindings==21.2.0 in /usr/local/lib/python
3.10/dist-packages (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/as
signment2//colab_requirements.txt (line 4)) (21.2.0)
Collecting arrow==1.2.3 (from -r /content/drive/My Drive/CS6353/Assignments/assignmen
t2/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/assig
nment2/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/assig
nment2/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/assignme
nt2/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/assignme
nt2/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-pack
ages (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//col
ab_requirements.txt (line 10)) (0.2.0)
Collecting beautifulsoup4==4.12.2 (from -r /content/drive/My Drive/CS6353/Assignment
s/assignment2/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/assignme
nt2/assignment2//colab_requirements.txt (line 12))
  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/ass
ignment2/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/assignmen
t2/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/Assignme
nts/assignment2/assignment2//colab_requirements.txt (line 15))
  Downloading charset_normalizer-3.2.0-cp310-cp310-manylinux_2_17_x86_64.manylinux201
4_x86_64.whl.metadata (31 kB)
Collecting comm==0.1.4 (from -r /content/drive/My Drive/CS6353/Assignments/assignment
2/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/assig
nment2/assignment2//colab_requirements.txt (line 17))
  Downloading contourpy-1.1.0-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.
whl.metadata (5.7 kB)
Collecting cycler==0.11.0 (from -r /content/drive/My Drive/CS6353/Assignments/assignm
ent2/assignment2//colab_requirements.txt (line 18))
  Downloading cycler-0.11.0-py3-none-any.whl.metadata (785 bytes)
Collecting debugpy==1.6.7.post1 (from -r /content/drive/My Drive/CS6353/Assignments/a
ssignment2/assignment2//colab_requirements.txt (line 19))
  Downloading debugpy-1.6.7.post1-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86
_64.whl.metadata (1.1 kB)
Requirement already satisfied: decorator<=5.0 in /usr/local/lib/python3.10/dist-packa
ges (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//cola
b_requirements.txt (line 20)) (4.4.2)
Requirement already satisfied: defusedxml==0.7.1 in /usr/local/lib/python3.10/dist-pa
ckages (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//c
olab_requirements.txt (line 21)) (0.7.1)
Collecting executing==1.2.0 (from -r /content/drive/My Drive/CS6353/Assignments/assig
nment2/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/Assignment
s/assignment2/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/assi
gnment2/assignment2//colab_requirements.txt (line 24))
  Downloading fonttools-4.42.1-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_6
4.whl.metadata (150 kB)
  ──────────────────────────────────────── 151.0/151.0 kB 5.1 MB/s eta 0:00:00
Collecting fqdn==1.5.1 (from -r /content/drive/My Drive/CS6353/Assignments/assignment
2/assignment2//colab_requirements.txt (line 25))
  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/
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/assign
ment2/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-pac
kages (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//co
lab_requirements.txt (line 28)) (5.5.6)
Requirement already satisfied: ipython<=7.34.0 in /usr/local/lib/python3.10/dist-pack
ages (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//col
ab_requirements.txt (line 29)) (7.34.0)
Collecting isoduration==20.11.0 (from -r /content/drive/My Drive/CS6353/Assignments/a
ssignment2/assignment2//colab_requirements.txt (line 30))
  Downloading isoduration-20.11.0-py3-none-any.whl.metadata (5.7 kB)
```

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Collecting jedi==0.19.0 (from -r /content/drive/My Drive/CS6353/Assignments/assignmen
t2/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/assignme
nt2/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/assignme
nt2/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/assig
nment2/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/ass
ignment2/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/CS635
3/Assignments/assignment2/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/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/ass
ignment2/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-p
ackages (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//
colab_requirements.txt (line 39)) (6.1.12)
Collecting jupyter_core==5.3.1 (from -r /content/drive/My Drive/CS6353/Assignments/as
signment2/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 Drive/CS6353/Assignments/
assignment2/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/As
signments/assignment2/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/assi
gnment2/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/Assignm
ents/assignment2/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/Assignme
nts/assignment2/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/assi
gnment2/assignment2//colab_requirements.txt (line 46))
  Downloading kiwisolver-1.4.5-cp310-cp310-manylinux_2_12_x86_64.manylinux2010_x86_6
4.whl.metadata (6.4 kB)
Collecting MarkupSafe==2.1.3 (from -r /content/drive/My Drive/CS6353/Assignments/assi
gnment2/assignment2//colab_requirements.txt (line 47))
  Downloading MarkupSafe-2.1.3-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_6
4.whl.metadata (3.0 kB)
Collecting matplotlib==3.7.2 (from -r /content/drive/My Drive/CS6353/Assignments/assi
gnment2/assignment2//colab_requirements.txt (line 48))
  Downloading matplotlib-3.7.2-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_6
4.whl.metadata (5.6 kB)
Collecting matplotlib-inline==0.1.6 (from -r /content/drive/My Drive/CS6353/Assignmen
ts/assignment2/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/assignm
ent2/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/assign
ment2/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/assig
nment2/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/assign
ment2/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/as
signment2/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/a
ssignment2/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 Drive/CS6353/Assignments/assi
gnment2/assignment2//colab_requirements.txt (line 56))
  Downloading numpy-1.23.5-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.wh
l.metadata (2.3 kB)
Collecting overrides==7.4.0 (from -r /content/drive/My Drive/CS6353/Assignments/assig
nment2/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/assign
ment2/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/assignme
nt2/assignment2//colab_requirements.txt (line 59))
  Downloading pandas-1.5.3-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.wh
l.metadata (11 kB)
Collecting pandocfilters==1.5.0 (from -r /content/drive/My Drive/CS6353/Assignments/a
ssignment2/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/assignmen
t2/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/assignm
ent2/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-p
ackages (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//
colab_requirements.txt (line 63)) (0.7.5)
Collecting Pillow==10.0.0 (from -r /content/drive/My Drive/CS6353/Assignments/assignm
ent2/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/a
ssignment2/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/Assignme
nts/assignment2/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/Assignment
s/assignment2/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-packag
es (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//colab
_requirements.txt (line 68)) (5.9.5)
Requirement already satisfied: ptyprocess==0.7.0 in /usr/local/lib/python3.10/dist-pa

```
ckages (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//c
olab_requirements.txt (line 69)) (0.7.0)
Collecting pure-eval==0.2.2 (from -r /content/drive/My Drive/CS6353/Assignments/assig
nment2/assignment2//colab_requirements.txt (line 70))
  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/assign
ment2/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/assig
nment2/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/assig
nment2/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/di
st-packages (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignmen
t2//colab_requirements.txt (line 74)) (2.8.2)
Collecting python-json-logger==2.0.7 (from -r /content/drive/My Drive/CS6353/Assignme
nts/assignment2/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/assignmen
t2/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/assignme
nt2/assignment2//colab_requirements.txt (line 77))
  Downloading PyYAML-6.0.1-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.wh
l.metadata (2.1 kB)
Requirement already satisfied: pyzmq<25 in /usr/local/lib/python3.10/dist-packages (f
rom -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//colab_requ
irements.txt (line 78)) (24.0.1)
Collecting referencing==0.30.2 (from -r /content/drive/My Drive/CS6353/Assignments/as
signment2/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/assig
nment2/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/Assignmen
ts/assignment2/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/Assignmen
ts/assignment2/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/assignm
ent2/assignment2//colab_requirements.txt (line 83))
  Downloading rpds_py-0.9.2-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.wh
l.metadata (3.7 kB)
Collecting scipy==1.11.2 (from -r /content/drive/My Drive/CS6353/Assignments/assignme
nt2/assignment2//colab_requirements.txt (line 84))
  Downloading scipy-1.11.2-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.wh
l.metadata (59 kB)
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Collecting seaborn==0.12.2 (from -r /content/drive/My Drive/CS6353/Assignments/assign
ment2/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/assi
gnment2/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/assignment2//colab_re
quirements.txt (line 87)) (1.16.0)
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Collecting sniffio==1.3.0 (from -r /content/drive/My Drive/CS6353/Assignments/assignm
ent2/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/assig
nment2/assignment2//colab_requirements.txt (line 89))
  Downloading soupsieve-2.4.1-py3-none-any.whl.metadata (4.7 kB)
Collecting stack-data==0.6.2 (from -r /content/drive/My Drive/CS6353/Assignments/assi
gnment2/assignment2//colab_requirements.txt (line 90))
  Downloading stack_data-0.6.2-py3-none-any.whl.metadata (18 kB)
Collecting terminado==0.17.1 (from -r /content/drive/My Drive/CS6353/Assignments/assi
gnment2/assignment2//colab_requirements.txt (line 91))
  Downloading terminado-0.17.1-py3-none-any.whl.metadata (5.9 kB)
Collecting tinycss2==1.2.1 (from -r /content/drive/My Drive/CS6353/Assignments/assign
ment2/assignment2//colab_requirements.txt (line 92))
  Downloading tinycss2-1.2.1-py3-none-any.whl.metadata (3.0 kB)
Collecting tornado<=6.3.2 (from -r /content/drive/My Drive/CS6353/Assignments/assignm
ent2/assignment2//colab_requirements.txt (line 93))
  Downloading tornado-6.3.2-cp38-abi3-manylinux_2_5_x86_64.manylinux1_x86_64.manylinu
x_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/assig
nment2/assignment2//colab_requirements.txt (line 94))
  Downloading traitlets-5.9.0-py3-none-any.whl.metadata (10 kB)
Collecting tzdata==2023.3 (from -r /content/drive/My Drive/CS6353/Assignments/assignm
ent2/assignment2//colab_requirements.txt (line 95))
  Downloading tzdata-2023.3-py2.py3-none-any.whl.metadata (1.4 kB)
Collecting uri-template==1.3.0 (from -r /content/drive/My Drive/CS6353/Assignments/as
signment2/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/assignm
ent2/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/assignm
ent2/assignment2//colab_requirements.txt (line 98))
  Downloading wcwidth-0.2.6-py2.py3-none-any.whl.metadata (11 kB)
Collecting webcolors==1.13 (from -r /content/drive/My Drive/CS6353/Assignments/assign
ment2/assignment2//colab_requirements.txt (line 99))
  Downloading webcolors-1.13-py3-none-any.whl.metadata (2.6 kB)
Requirement already satisfied: webencodings==0.5.1 in /usr/local/lib/python3.10/dist-
packages (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment
2//colab_requirements.txt (line 100)) (0.5.1)
Collecting websocket-client==1.6.2 (from -r /content/drive/My Drive/CS6353/Assignment
s/assignment2/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-packa
ges (from anyio==3.7.1->-r /content/drive/My Drive/CS6353/Assignments/assignment2/ass
ignment2//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/a
ssignment2/assignment2//colab_requirements.txt (line 7)) (4.12.2)
Collecting jupyter_client<8.0 (from -r /content/drive/My Drive/CS6353/Assignments/ass
ignment2/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/assignme
nt2//colab_requirements.txt (line 43)) (2.0.1)
Requirement already satisfied: ipython-genutils in /usr/local/lib/python3.10/dist-pac
kages (from ipykernel<=5.5.6->-r /content/drive/My Drive/CS6353/Assignments/assignmen
t2/assignment2//colab_requirements.txt (line 28)) (0.2.0)
Requirement already satisfied: setuptools>=18.5 in /usr/local/lib/python3.10/dist-pac
kages (from ipython<=7.34.0->-r /content/drive/My Drive/CS6353/Assignments/assignment
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2/assignment2//colab_requirements.txt (line 29)) (71.0.4)
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/a
ssignment2//colab_requirements.txt (line 39)) (0.4)
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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)
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Downloading bleach-6.0.0-py3-none-any.whl (162 kB)
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Downloading certifi-2023.7.22-py3-none-any.whl (158 kB)
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l (300 kB)
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4.whl (3.0 MB)
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Downloading Jinja2-3.1.2-py3-none-any.whl (133 kB)
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Downloading json5-0.9.14-py2.py3-none-any.whl (19 kB)
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Downloading jupyter_server_terminals-0.4.4-py3-none-any.whl (13 kB)
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Downloading matplotlib_inline-0.1.6-py3-none-any.whl (9.4 kB)
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Downloading notebook_shim-0.2.3-py3-none-any.whl (13 kB)
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Downloading pexpect-4.8.0-py2.py3-none-any.whl (59 kB)
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Downloading Pillow-10.0.0-cp310-cp310-manylinux_2_28_x86_64.whl (3.4 MB)
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Downloading platformdirs-3.10.0-py3-none-any.whl (17 kB)
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Downloading pure_eval-0.2.2-py3-none-any.whl (11 kB)
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Installing collected packages: wcwidth, pytz, pure-eval, json5, fastjsonschema, execu
ting, appnope, websocket-client, webcolors, urllib3, uri-template, tzdata, traitlets,
tornado, tinycss2, soupsieve, sniffio, Send2Trash, rpds-py, rfc3986-validator, rfc333
9-validator, PyYAML, python-json-logger, pyparsing, Pygments, pycparser, prompt-toolk
it, prometheus-client, platformdirs, Pillow, pexpect, parso, pandocfilters, packagin
g, overrides, numpy, nest-asyncio, mistune, MarkupSafe, kiwisolver, jupyterlab-pygmen
ts, jsonpointer, idna, fqdn, fonttools, debugpy, cycler, charset-normalizer, certifi,
bleach, Babel, attrs, async-lru, asttokens, terminado, stack-data, scipy, requests, r
eferencing, pandas, matplotlib-inline, jupyter_core, Jinja2, jedi, imageio, contourp
y, comm, cffi, beautifulsoup4, arrow, matplotlib, jupyter_server_terminals, jupyter_c
lient, jsonschema-specifications, isoduration, seaborn, jsonschema, nbformat, nbclien
t, jupyter-events, nbconvert, jupyter_server, notebook_shim, jupyterlab_server, jupyt
er-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 2.20.0
    Uninstalling fastjsonschema-2.20.0:
      Successfully uninstalled fastjsonschema-2.20.0
  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 24.8.0
         Uninstalling webcolors-24.8.0:
            Successfully uninstalled webcolors-24.8.0
      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 2024.1
         Uninstalling tzdata-2024.1:
            Successfully uninstalled tzdata-2024.1
      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
         Uninstalling tornado-6.3.3:
            Successfully uninstalled tornado-6.3.3
      Attempting uninstall: tinycss2
         Found existing installation: tinycss2 1.3.0
         Uninstalling tinycss2-1.3.0:
            Successfully uninstalled tinycss2-1.3.0
      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 0.20.0
         Uninstalling rpds-py-0.20.0:
            Successfully uninstalled rpds-py-0.20.0
      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 3.1.4
         Uninstalling pyparsing-3.1.4:
            Successfully uninstalled pyparsing-3.1.4
      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 3.0.47
    Uninstalling prompt_toolkit-3.0.47:
      Successfully uninstalled prompt_toolkit-3.0.47
  Attempting uninstall: prometheus-client
    Found existing installation: prometheus_client 0.21.0
    Uninstalling prometheus_client-0.21.0:
      Successfully uninstalled prometheus_client-0.21.0
  Attempting uninstall: platformdirs
    Found existing installation: platformdirs 4.3.6
    Uninstalling platformdirs-4.3.6:
      Successfully uninstalled platformdirs-4.3.6
  Attempting uninstall: Pillow
    Found existing installation: pillow 10.4.0
    Uninstalling pillow-10.4.0:
      Successfully uninstalled pillow-10.4.0
  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 24.1
    Uninstalling packaging-24.1:
      Successfully uninstalled packaging-24.1
  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 0.8.4
    Uninstalling mistune-0.8.4:
      Successfully uninstalled mistune-0.8.4
  Attempting uninstall: MarkupSafe
    Found existing installation: MarkupSafe 2.1.5
    Uninstalling MarkupSafe-2.1.5:
      Successfully uninstalled MarkupSafe-2.1.5
  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: idna
    Found existing installation: idna 3.10
    Uninstalling idna-3.10:
      Successfully uninstalled idna-3.10
  Attempting uninstall: fonttools
```

```
    Found existing installation: fonttools 4.53.1
    Uninstalling fonttools-4.53.1:
      Successfully uninstalled fonttools-4.53.1
  Attempting uninstall: debugpy
    Found existing installation: debugpy 1.6.6
    Uninstalling debugpy-1.6.6:
      Successfully uninstalled debugpy-1.6.6
  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 3.3.2
    Uninstalling charset-normalizer-3.3.2:
      Successfully uninstalled charset-normalizer-3.3.2
  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 6.1.0
    Uninstalling bleach-6.1.0:
      Successfully uninstalled bleach-6.1.0
  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 2.1.4
    Uninstalling pandas-2.1.4:
      Successfully uninstalled pandas-2.1.4
  Attempting uninstall: matplotlib-inline
    Found existing installation: matplotlib-inline 0.1.7
    Uninstalling matplotlib-inline-0.1.7:
      Successfully uninstalled matplotlib-inline-0.1.7
  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 2.35.1
    Uninstalling imageio-2.35.1:
      Successfully uninstalled imageio-2.35.1
  Attempting uninstall: contourpy
    Found existing installation: contourpy 1.3.0
    Uninstalling contourpy-1.3.0:
      Successfully uninstalled contourpy-1.3.0
  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 3.7.1
    Uninstalling matplotlib-3.7.1:
      Successfully uninstalled matplotlib-3.7.1
  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 2023.12.1
    Uninstalling jsonschema-specifications-2023.12.1:
      Successfully uninstalled jsonschema-specifications-2023.12.1
  Attempting uninstall: seaborn
    Found existing installation: seaborn 0.13.1
    Uninstalling seaborn-0.13.1:
      Successfully uninstalled seaborn-0.13.1
  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 0.10.0
    Uninstalling nbclient-0.10.0:
      Successfully uninstalled nbclient-0.10.0
  Attempting uninstall: nbconvert
    Found existing installation: nbconvert 6.5.4
    Uninstalling nbconvert-6.5.4:
      Successfully uninstalled nbconvert-6.5.4
  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 package
```

```
s that are installed. This behaviour is the source of the following dependency confli
cts.
albucore 0.0.16 requires numpy>=1.24, but you have numpy 1.23.5 which is incompatibl
e.
albumentations 1.4.15 requires numpy>=1.24.4, but you have numpy 1.23.5 which is inco
mpatible.
bigframes 1.18.0 requires numpy>=1.24.0, but you have numpy 1.23.5 which is incompati
ble.
bokeh 3.4.3 requires contourpy>=1.2, but you have contourpy 1.1.0 which is incompatib
le.
chex 0.1.86 requires numpy>=1.24.1, but you have numpy 1.23.5 which is incompatible.
cudf-cu12 24.4.1 requires pandas<2.2.2dev0,>=2.0, but you have pandas 1.5.3 which is
incompatible.
google-colab 1.0.0 requires pandas==2.1.4, but you have pandas 1.5.3 which is incompa
tible.
google-colab 1.0.0 requires requests==2.32.3, but you have requests 2.31.0 which is i
ncompatible.
google-colab 1.0.0 requires tornado==6.3.3, but you have tornado 6.3.2 which is incom
patible.
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.
mizani 0.11.4 requires pandas>=2.1.0, but you have pandas 1.5.3 which is incompatibl
e.
pandas-stubs 2.1.4.231227 requires numpy>=1.26.0; python_version < "3.13", but you ha
ve numpy 1.23.5 which is incompatible.
plotnine 0.13.6 requires pandas<3.0.0,>=2.1.0, but you have pandas 1.5.3 which is inc
ompatible.
scikit-image 0.24.0 requires imageio>=2.33, but you have imageio 2.31.1 which is inco
mpatible.
xarray 2024.9.0 requires numpy>=1.24, but you have numpy 1.23.5 which is incompatibl
e.
xarray 2024.9.0 requires pandas>=2.1, but you have pandas 1.5.3 which is incompatibl
e.
Successfully installed Babel-2.12.1 Jinja2-3.1.2 MarkupSafe-2.1.3 Pillow-10.0.0 PyYAM
L-6.0.1 Pygments-2.16.1 Send2Trash-1.8.2 appnope-0.1.3 arrow-1.2.3 asttokens-2.2.1 as
ync-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 im
ageio-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 jupy
ter_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 platfor
mdirs-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 request
s-2.31.0 rfc3339-validator-0.1.4 rfc3986-validator-0.1.1 rpds-py-0.9.2 scipy-1.11.2 s
eaborn-0.12.2 sniffio-1.3.0 soupsieve-2.4.1 stack-data-0.6.2 terminado-0.17.1 tinycss
2-1.2.1 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
```

Multiclass Support Vector Machine 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.

In this exercise you will:

- implement a fully-vectorized **loss function** for the SVM
- implement the fully-vectorized expression for its **analytic gradient**
- **check your implementation** using numerical gradient
- use a validation set to **tune the learning rate and regularization** strength
- **optimize** the loss function with **SGD**
- **visualize** the final learned weights

```
In [ ]: # Run some setup code for this notebook.
        from __future__ import print_function
        import random
        import numpy as np
        from cs6353.data_utils import load_CIFAR10
        import matplotlib.pyplot as plt


        # This is a bit of magic to make matplotlib figures appear inline in the
        # notebook rather than in a new window.
        %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'

        # Some more magic so that the notebook will reload external python modules;
        # see http://stackoverflow.com/questions/1907993/autoreload-of-modules-in-ipython
        %load_ext autoreload
        %autoreload 2
```

CIFAR-10 Data Loading and Preprocessing

```
In [ ]: # Load the raw CIFAR-10 data.
        cifar10_dir = 'cs6353/datasets/cifar-10-batches-py'

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

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

        # As a sanity check, we print out the size of the training and test data.
        print('Training data shape: ', X_train.shape)
        print('Training labels shape: ', y_train.shape)
        print('Test data shape: ', X_test.shape)
        print('Test labels shape: ', y_test.shape)
```

```
Training data shape:  (50000, 32, 32, 3)
Training labels shape:  (50000,)
Test data shape:  (10000, 32, 32, 3)
Test labels shape:  (10000,)
```

In [ ]:
```python
# Visualize some examples from the dataset.
# We show a few examples of training images from each class.
classes = ['plane', 'car', 'bird', 'cat', 'deer', 'dog', 'frog', 'horse', 'ship', 'tru
num_classes = len(classes)
samples_per_class = 7
for y, cls in enumerate(classes):
    idxs = np.flatnonzero(y_train == y)
    idxs = np.random.choice(idxs, samples_per_class, replace=False)
    for i, idx in enumerate(idxs):
        plt_idx = i * num_classes + y + 1
        plt.subplot(samples_per_class, num_classes, plt_idx)
        plt.imshow(X_train[idx].astype('uint8'))
        plt.axis('off')
        if i == 0:
            plt.title(cls)
plt.show()
```
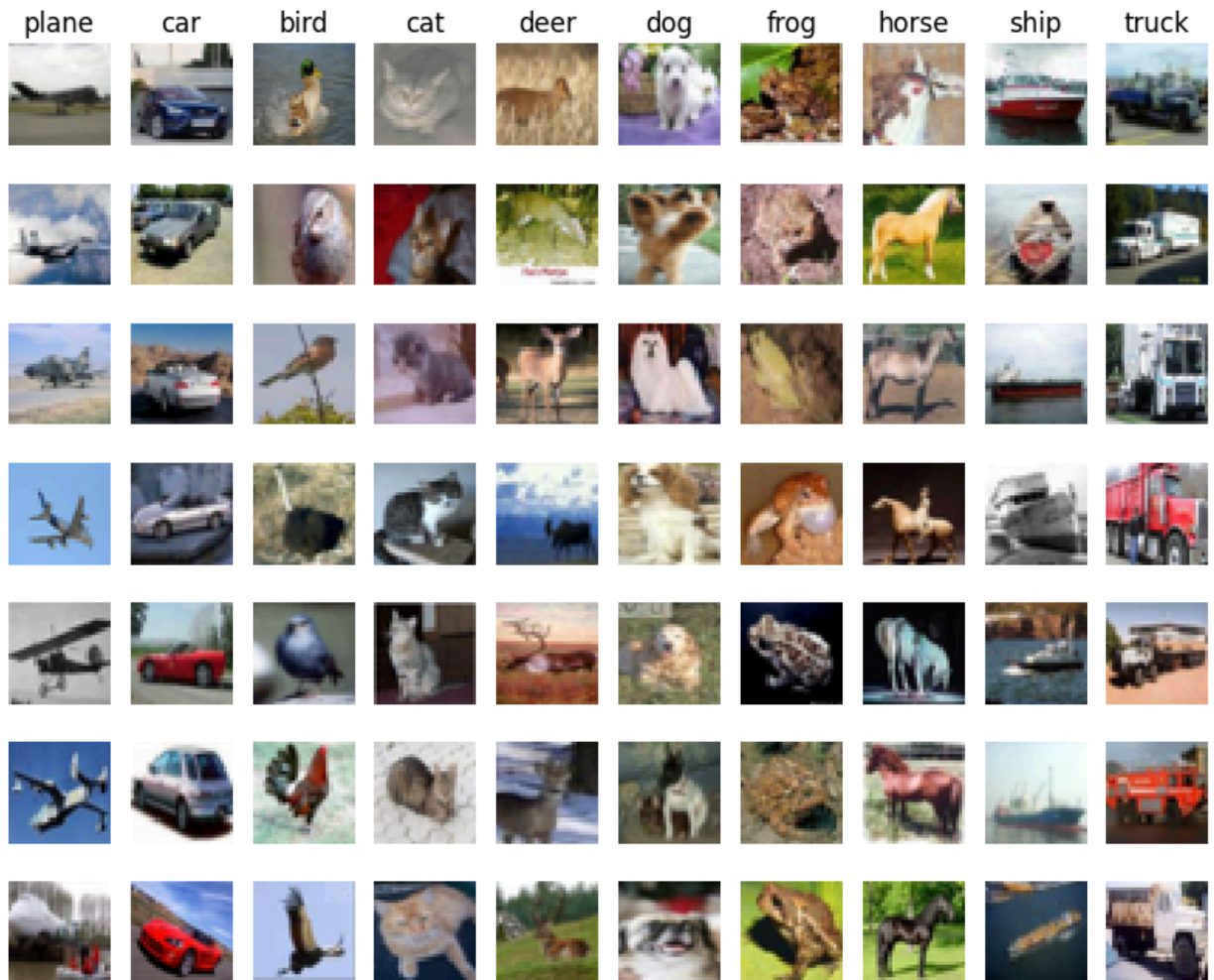

In [ ]:
```python
# Split the data into train, val, and test sets. In addition we will
# create a small development set as a subset of the training data;
# we can use this for development so our code runs faster.
num_training = 49000
num_validation = 1000
num_test = 1000
num_dev = 500

# Our validation set will be num_validation points from the original
# training set.
```

```python
mask = range(num_training, num_training + num_validation)
X_val = X_train[mask]
y_val = y_train[mask]

# Our training set will be the first num_train points from the original
# training set.
mask = range(num_training)
X_train = X_train[mask]
y_train = y_train[mask]

# We will also make a development set, which is a small subset of
# the training set.
mask = np.random.choice(num_training, num_dev, replace=False)
X_dev = X_train[mask]
y_dev = y_train[mask]

# We use the first num_test points of the original test set as our
# test set.
mask = range(num_test)
X_test = X_test[mask]
y_test = y_test[mask]

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)
```

```
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,)
```

In [ ]:
```python
# Preprocessing: reshape the image data into rows
X_train = np.reshape(X_train, (X_train.shape[0], -1))
X_val = np.reshape(X_val, (X_val.shape[0], -1))
X_test = np.reshape(X_test, (X_test.shape[0], -1))
X_dev = np.reshape(X_dev, (X_dev.shape[0], -1))

# As a sanity check, print out the shapes of the data
print('Training data shape: ', X_train.shape)
print('Validation data shape: ', X_val.shape)
print('Test data shape: ', X_test.shape)
print('dev data shape: ', X_dev.shape)
```

```
Training data shape:  (49000, 3072)
Validation data shape:  (1000, 3072)
Test data shape:  (1000, 3072)
dev data shape:  (500, 3072)
```

In [ ]:
```python
# Preprocessing: subtract the mean image
# first: compute the image mean based on the training data
mean_image = np.mean(X_train, axis=0)
print(mean_image[:10]) # print a few of the elements
plt.figure(figsize=(4,4))
plt.imshow(mean_image.reshape((32,32,3)).astype('uint8')) # visualize the mean image
plt.show()
```

```
[130.64189796 135.98173469 132.47391837 130.05569388 135.34804082
 131.75402041 130.96055102 136.14328571 132.47636735 131.48467347]
```
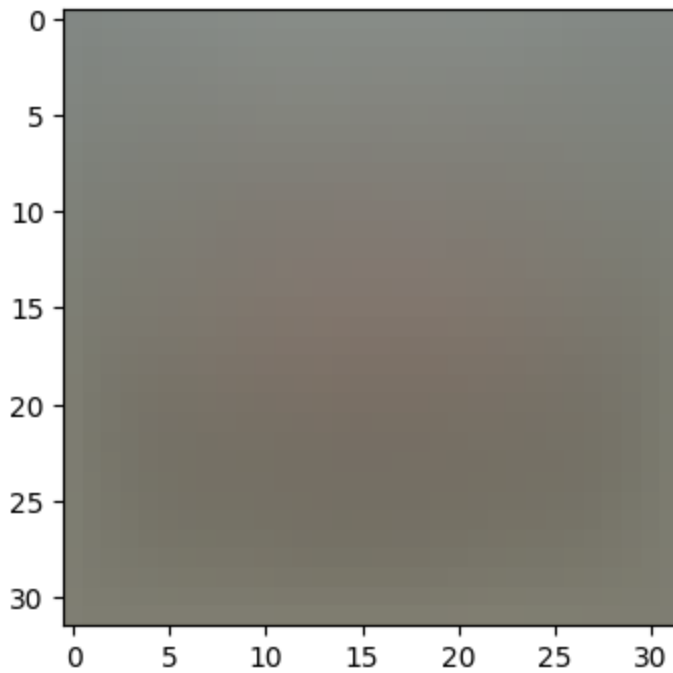

In [ ]:
```python
# second: subtract the mean image from train and test data
X_train -= mean_image
X_val -= mean_image
X_test -= mean_image
X_dev -= mean_image
```

In [ ]:
```python
# third: append the bias dimension of ones (i.e. bias trick) so that our SVM
# only has to worry about optimizing a single weight matrix W.
X_train = np.hstack([X_train, np.ones((X_train.shape[0], 1))])
X_val = np.hstack([X_val, np.ones((X_val.shape[0], 1))])
X_test = np.hstack([X_test, np.ones((X_test.shape[0], 1))])
X_dev = np.hstack([X_dev, np.ones((X_dev.shape[0], 1))])

print(X_train.shape, X_val.shape, X_test.shape, X_dev.shape)
```

```
(49000, 3073) (1000, 3073) (1000, 3073) (500, 3073)
```

SVM Classifier

Your code for this section will all be written inside **cs6353/classifiers/linear_svm.py**.

As you can see, we have prefilled the function `svm_loss_naive` which uses for loops to evaluate the multiclass SVM loss function.

In [ ]:
```python
# Evaluate the naive implementation of the loss we provided for you:
from cs6353.classifiers.linear_svm import svm_loss_naive
import time

# generate a random SVM weight matrix of small numbers
W = np.random.randn(3073, 10) * 0.0001

loss, grad = svm_loss_naive(W, X_dev, y_dev, 0.000005)
```

```
print('grad: ', grad)
print('loss: %f' % (loss, ))
```

```
grad:  [[-7.58906714e+00 -1.88964172e+01  2.29122651e-01 ... -1.30679194e+01
  -2.68278514e+01 -3.43442310e+01]
 [-1.58692786e+01 -1.64492239e+01  5.92289490e+00 ... -1.48404657e+01
  -3.08738904e+01 -3.80082373e+01]
 [-4.13668257e+01 -2.11124593e+01  1.66665661e+01 ... -1.23278091e+01
  -4.89268435e+01 -4.44916272e+01]
 ...
 [-2.09256629e+01 -1.61254797e+01  9.72253306e+00 ... -2.10444046e+01
   2.92848282e+01 -1.55055636e+01]
 [-3.73340300e+01 -1.88117226e+01  1.26799271e+01 ... -1.07235640e+01
   8.10160257e+00 -1.85803117e+01]
 [-6.99999995e-02 -2.86000001e-01 -1.70000000e-01 ...  8.40000005e-02
   5.99999688e-03  2.05999999e-01]]
loss: 8.830742
```

The `grad` returned from the function above is right now all zero. Derive and implement the gradient for the SVM cost function and implement it inline inside the function `svm_loss_naive`. You will find it helpful to interleave your new code inside the existing function.

To check that you have correctly implemented the gradient correctly, you can numerically estimate the gradient of the loss function and compare the numeric estimate to the gradient that you computed. We have provided code that does this for you:

```
In [ ]:  # Once you've implemented the gradient, recompute it with the code below
         # and gradient check it with the function we provided for you

         # Compute the loss and its gradient at W.
         loss, grad = svm_loss_naive(W, X_dev, y_dev, 0.0)

         # Numerically compute the gradient along several randomly chosen dimensions, and
         # compare them with your analytically computed gradient. The numbers should match
         # almost exactly along all dimensions.
         from cs6353.gradient_check import grad_check_sparse
         f = lambda w: svm_loss_naive(w, X_dev, y_dev, 0.0)[0]
         grad_numerical = grad_check_sparse(f, W, grad)

         # do the gradient check once again with regularization turned on
         # you didn't forget the regularization gradient did you?
         loss, grad = svm_loss_naive(W, X_dev, y_dev, 5e1)
         f = lambda w: svm_loss_naive(w, X_dev, y_dev, 5e1)[0]
         grad_numerical = grad_check_sparse(f, W, grad)
```

```
numerical: -1.836874 analytic: -1.836874, relative error: 4.933138e-11
numerical: 7.346344 analytic: 7.346344, relative error: 1.374043e-11
numerical: -1.583480 analytic: -1.572928, relative error: 3.343141e-03
numerical: 2.739409 analytic: 2.739409, relative error: 2.377995e-11
numerical: 9.991404 analytic: 9.991404, relative error: 5.010525e-12
numerical: -33.077543 analytic: -33.077543, relative error: 5.846195e-12
numerical: 8.632547 analytic: 8.669070, relative error: 2.110998e-03
numerical: 0.766813 analytic: 0.766813, relative error: 1.443983e-10
numerical: -38.545572 analytic: -38.627434, relative error: 1.060759e-03
numerical: -8.611617 analytic: -8.611617, relative error: 1.130704e-11
numerical: 9.394738 analytic: 9.394738, relative error: 7.961307e-12
numerical: -3.066593 analytic: -3.066593, relative error: 1.101293e-10
numerical: -13.585245 analytic: -13.585245, relative error: 5.498565e-12
numerical: 1.604586 analytic: 1.604586, relative error: 9.601810e-11
numerical: 6.820640 analytic: 6.820640, relative error: 6.083431e-11
numerical: 15.238316 analytic: 15.238316, relative error: 1.963482e-11
numerical: 10.441361 analytic: 10.441361, relative error: 3.038765e-11
numerical: 10.989256 analytic: 11.041811, relative error: 2.385489e-03
numerical: -28.241544 analytic: -28.289356, relative error: 8.457706e-04
numerical: -8.099178 analytic: -8.099178, relative error: 1.960946e-11
```

Inline Question 1:

It is possible that once in a while a dimension in the gradient check will not match exactly. What could such a discrepancy be caused by? Is it a reason for concern? What is a simple example in one dimension where a gradient check could fail? How would change the margin affect of the frequency of this happening? *Hint: the SVM loss function is not strictly speaking differentiable*

Your Answer: The mismatch in the dimension of the gradient check can occur due to the SVM loss function not being continously differentiable. The SVM loss function is defined as max(0, x), where x is the difference between the scores of incorrect and correct classes plus delta. If x < 0 the loss gets clipped to 0. Hence, at the Hinge x = 0, the loss function is undefined and hence we cannot differentiate. This can cause the discrepancy.

We can skip the gradient update step when this error occurs. Since the occurrence of such an error is rare, it is not an cause of concern.

A simple example where the gradient check will fail is: Modulus function |x|, at x = 0 the gradient check for this function will fail.

Consider the function max(0, x). If we increase the magin delta, the possibility of x being negative reduces, hence the possibility of loss being 0 reduces and hence the frequency of gradient check failing reduces.

```python
In [ ]:   # Next implement the function svm_loss_vectorized; for now only compute the loss;
          # we will implement the gradient in a moment.
          tic = time.time()
          loss_naive, grad_naive = svm_loss_naive(W, X_dev, y_dev, 0.000005)
          toc = time.time()
          print('Naive loss: %e computed in %fs' % (loss_naive, toc - tic))

          from cs6353.classifiers.linear_svm import svm_loss_vectorized
          tic = time.time()
```

```python
loss_vectorized, _ = svm_loss_vectorized(W, X_dev, y_dev, 0.000005)
toc = time.time()
print('Vectorized loss: %e computed in %fs' % (loss_vectorized, toc - tic))

# The losses should match but your vectorized implementation should be much faster.
print('difference: %f' % (loss_naive - loss_vectorized))
```

```
Naive loss: 8.830742e+00 computed in 0.099236s
Vectorized loss: 8.830742e+00 computed in 0.011614s
difference: 0.000000
```

In [ ]:
```python
# Complete the implementation of svm_loss_vectorized, and compute the gradient
# of the loss function in a vectorized way.

# The naive implementation and the vectorized implementation should match, but
# the vectorized version should still be much faster.
tic = time.time()
_, grad_naive = svm_loss_naive(W, X_dev, y_dev, 0.000005)
toc = time.time()
print('Naive loss and gradient: computed in %fs' % (toc - tic))

tic = time.time()
_, grad_vectorized = svm_loss_vectorized(W, X_dev, y_dev, 0.000005)
toc = time.time()
print('Vectorized loss and gradient: computed in %fs' % (toc - tic))

# The loss is a single number, so it is easy to compare the values computed
# by the two implementations. The gradient on the other hand is a matrix, so
# we use the Frobenius norm to compare them.
difference = np.linalg.norm(grad_naive - grad_vectorized, ord='fro')
print('difference: %f' % difference)
```

```
Naive loss and gradient: computed in 0.091855s
Vectorized loss and gradient: computed in 0.009065s
difference: 0.000000
```

Stochastic Gradient Descent

We now have vectorized and efficient expressions for the loss, the gradient and our gradient matches the numerical gradient. We are therefore ready to do SGD to minimize the loss. Your code for this part will be written inside `cs6353/classifiers/linear_classifier.py`.

In [ ]:
```python
# In the file linear_classifier.py, implement SGD in the function
# LinearClassifier.train() and then run it with the code below.
from cs6353.classifiers import LinearSVM
svm = LinearSVM()
tic = time.time()
loss_hist = svm.train(X_train, y_train, learning_rate=1e-7, reg=2.5e4,
                      num_iters=1500, verbose=True)
toc = time.time()
print('That took %fs' % (toc - tic))
```

```
iteration 0 / 1500: loss 796.412384
iteration 100 / 1500: loss 290.687019
iteration 200 / 1500: loss 108.979117
iteration 300 / 1500: loss 42.586333
iteration 400 / 1500: loss 18.861781
iteration 500 / 1500: loss 10.370017
iteration 600 / 1500: loss 6.483616
iteration 700 / 1500: loss 5.515384
iteration 800 / 1500: loss 5.363760
iteration 900 / 1500: loss 5.640452
iteration 1000 / 1500: loss 4.680338
iteration 1100 / 1500: loss 5.723385
iteration 1200 / 1500: loss 5.408608
iteration 1300 / 1500: loss 4.616177
iteration 1400 / 1500: loss 4.930543
That took 9.644955s
```

In [ ]:
```python
# A useful debugging strategy is to plot the loss as a function of
# iteration number:
plt.plot(loss_hist)
plt.xlabel('Iteration number')
plt.ylabel('Loss value')
plt.show()
```
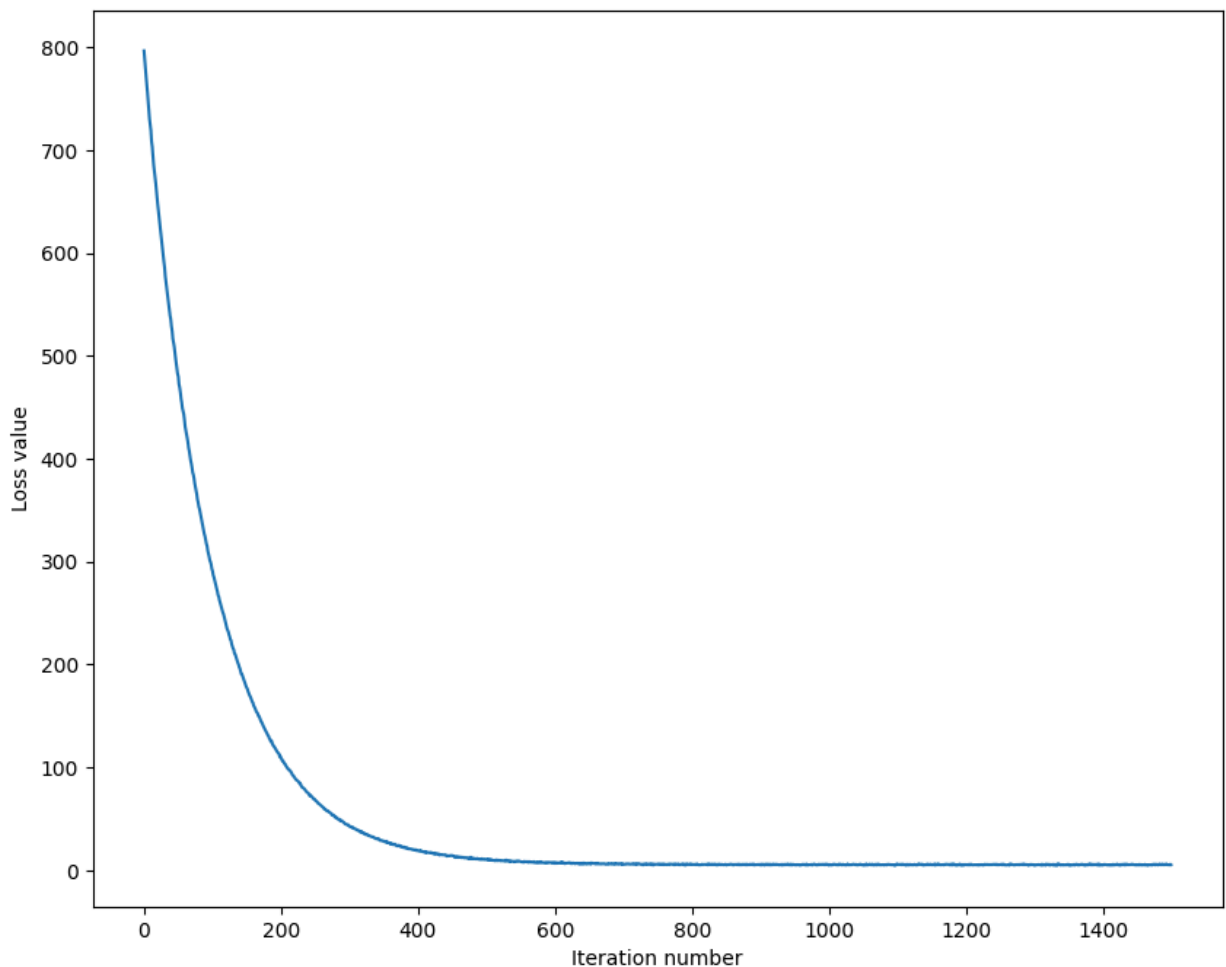

In [ ]:
```python
# Write the LinearSVM.predict function and evaluate the performance on both the
# training and validation set
y_train_pred = svm.predict(X_train)
print('training accuracy: %f' % (np.mean(y_train == y_train_pred), ))
```

```
y_val_pred = svm.predict(X_val)
print('validation accuracy: %f' % (np.mean(y_val == y_val_pred), ))
```

```
training accuracy: 0.371286
validation accuracy: 0.376000
```

In [ ]:
```
# Use the validation set to tune hyperparameters (regularization strength and
# learning rate). You should experiment with different ranges for the learning
# rates and regularization strengths; if you are careful you should be able to
# get a classification accuracy of about 0.4 on the validation set.
learning_rates = [1e-7, 2e-7, 5e-6, 5e-5]
regularization_strengths = [5e3, 2.5e4, 5e4, 1e5]

# results is dictionary mapping tuples of the form
# (learning_rate, regularization_strength) to tuples of the form
# (training_accuracy, validation_accuracy). The accuracy is simply the fraction
# of data points that are correctly classified.
results = {}
best_val = -1   # The highest validation accuracy that we have seen so far.
best_svm = None # The LinearSVM object that achieved the highest validation rate.


################################################################################
# TODO:                                                                        #
# Write code that chooses the best hyperparameters by tuning on the validation #
# set. For each combination of hyperparameters, train a linear SVM on the      #
# training set, compute its accuracy on the training and validation sets, and  #
# store these numbers in the results dictionary. In addition, store the best   #
# validation accuracy in best_val and the LinearSVM object that achieves this  #
# accuracy in best_svm.                                                        #
#                                                                              #
# Hint: You should use a small value for num_iters as you develop your         #
# validation code so that the SVMs don't take much time to train; once you are #
# confident that your validation code works, you should rerun the validation   #
# code with a larger value for num_iters.                                      #
################################################################################
for lr in learning_rates:
    for reg in regularization_strengths:

        svm = LinearSVM()

        svm.train(X_train, y_train, learning_rate=lr, reg=reg, num_iters=1500, verbose

        y_train_pred = svm.predict(X_train)
        y_val_pred = svm.predict(X_val)

        train_results = y_train_pred == y_train
        y_train_accuracy = np.mean(train_results)

        val_results = y_val_pred == y_val
        y_val_accuracy = np.mean(val_results)

        results[(lr, reg)] = (y_train_accuracy, y_val_accuracy)

        if y_val_accuracy > best_val:
            best_val = y_val_accuracy
            best_svm = svm

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

```python
# 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)
```

```
iteration 0 / 1500: loss 178.244227
iteration 100 / 1500: loss 134.383499
iteration 200 / 1500: loss 108.965742
iteration 300 / 1500: loss 89.827161
iteration 400 / 1500: loss 73.827566
iteration 500 / 1500: loss 60.892688
iteration 600 / 1500: loss 50.312921
iteration 700 / 1500: loss 41.541130
iteration 800 / 1500: loss 35.354586
iteration 900 / 1500: loss 28.906567
iteration 1000 / 1500: loss 24.374831
iteration 1100 / 1500: loss 21.776227
iteration 1200 / 1500: loss 17.810968
iteration 1300 / 1500: loss 15.919390
iteration 1400 / 1500: loss 13.630636
iteration 0 / 1500: loss 791.273070
iteration 100 / 1500: loss 289.199177
iteration 200 / 1500: loss 108.022782
iteration 300 / 1500: loss 42.459306
iteration 400 / 1500: loss 18.652796
iteration 500 / 1500: loss 10.216656
iteration 600 / 1500: loss 7.226874
iteration 700 / 1500: loss 6.247032
iteration 800 / 1500: loss 5.329904
iteration 900 / 1500: loss 6.004492
iteration 1000 / 1500: loss 5.448198
iteration 1100 / 1500: loss 5.389966
iteration 1200 / 1500: loss 5.219112
iteration 1300 / 1500: loss 5.644886
iteration 1400 / 1500: loss 4.886158
iteration 0 / 1500: loss 1563.660630
iteration 100 / 1500: loss 210.325976
iteration 200 / 1500: loss 32.064180
iteration 300 / 1500: loss 8.797855
iteration 400 / 1500: loss 6.379050
iteration 500 / 1500: loss 5.811982
iteration 600 / 1500: loss 5.793851
iteration 700 / 1500: loss 5.642848
iteration 800 / 1500: loss 5.202007
iteration 900 / 1500: loss 4.934217
iteration 1000 / 1500: loss 5.627553
iteration 1100 / 1500: loss 5.560569
iteration 1200 / 1500: loss 5.297981
iteration 1300 / 1500: loss 5.244115
iteration 1400 / 1500: loss 5.524269
iteration 0 / 1500: loss 3073.123079
iteration 100 / 1500: loss 58.998161
iteration 200 / 1500: loss 7.132229
iteration 300 / 1500: loss 5.966786
iteration 400 / 1500: loss 6.069582
iteration 500 / 1500: loss 6.156074
iteration 600 / 1500: loss 6.090922
iteration 700 / 1500: loss 5.830623
iteration 800 / 1500: loss 6.569839
iteration 900 / 1500: loss 6.384720
iteration 1000 / 1500: loss 6.130254
iteration 1100 / 1500: loss 5.692147
iteration 1200 / 1500: loss 6.943978
iteration 1300 / 1500: loss 5.897260
iteration 1400 / 1500: loss 6.606903
```

```
iteration 0 / 1500: loss 172.598569
iteration 100 / 1500: loss 110.170134
iteration 200 / 1500: loss 75.924439
iteration 300 / 1500: loss 50.918345
iteration 400 / 1500: loss 35.379410
iteration 500 / 1500: loss 25.040118
iteration 600 / 1500: loss 19.052712
iteration 700 / 1500: loss 14.101669
iteration 800 / 1500: loss 10.694302
iteration 900 / 1500: loss 9.092919
iteration 1000 / 1500: loss 7.707675
iteration 1100 / 1500: loss 6.722602
iteration 1200 / 1500: loss 6.305849
iteration 1300 / 1500: loss 5.275060
iteration 1400 / 1500: loss 5.666545
iteration 0 / 1500: loss 783.232515
iteration 100 / 1500: loss 106.819093
iteration 200 / 1500: loss 18.907263
iteration 300 / 1500: loss 7.052838
iteration 400 / 1500: loss 5.505619
iteration 500 / 1500: loss 5.517656
iteration 600 / 1500: loss 5.581646
iteration 700 / 1500: loss 4.754594
iteration 800 / 1500: loss 5.220277
iteration 900 / 1500: loss 5.582272
iteration 1000 / 1500: loss 5.370475
iteration 1100 / 1500: loss 5.067590
iteration 1200 / 1500: loss 5.661360
iteration 1300 / 1500: loss 5.349802
iteration 1400 / 1500: loss 5.402219
iteration 0 / 1500: loss 1562.243201
iteration 100 / 1500: loss 32.191925
iteration 200 / 1500: loss 6.885046
iteration 300 / 1500: loss 5.602807
iteration 400 / 1500: loss 6.131675
iteration 500 / 1500: loss 5.640953
iteration 600 / 1500: loss 5.735482
iteration 700 / 1500: loss 5.928857
iteration 800 / 1500: loss 5.743055
iteration 900 / 1500: loss 5.531828
iteration 1000 / 1500: loss 5.203421
iteration 1100 / 1500: loss 6.086186
iteration 1200 / 1500: loss 5.902380
iteration 1300 / 1500: loss 5.302349
iteration 1400 / 1500: loss 5.934050
iteration 0 / 1500: loss 3098.534357
iteration 100 / 1500: loss 7.130491
iteration 200 / 1500: loss 6.094228
iteration 300 / 1500: loss 6.065124
iteration 400 / 1500: loss 6.282524
iteration 500 / 1500: loss 6.191154
iteration 600 / 1500: loss 5.976392
iteration 700 / 1500: loss 5.975025
iteration 800 / 1500: loss 5.645989
iteration 900 / 1500: loss 5.807639
iteration 1000 / 1500: loss 5.936774
iteration 1100 / 1500: loss 5.835507
iteration 1200 / 1500: loss 5.958050
iteration 1300 / 1500: loss 6.819106
iteration 1400 / 1500: loss 5.669680
```

```
iteration 0 / 1500: loss 173.198183
iteration 100 / 1500: loss 20.853773
iteration 200 / 1500: loss 18.109174
iteration 300 / 1500: loss 15.733888
iteration 400 / 1500: loss 13.055410
iteration 500 / 1500: loss 13.854221
iteration 600 / 1500: loss 10.420108
iteration 700 / 1500: loss 14.229794
iteration 800 / 1500: loss 13.924428
iteration 900 / 1500: loss 15.281499
iteration 1000 / 1500: loss 16.875358
iteration 1100 / 1500: loss 13.741402
iteration 1200 / 1500: loss 23.626028
iteration 1300 / 1500: loss 13.205194
iteration 1400 / 1500: loss 18.871571
iteration 0 / 1500: loss 779.975295
iteration 100 / 1500: loss 23.130887
iteration 200 / 1500: loss 33.690605
iteration 300 / 1500: loss 28.841234
iteration 400 / 1500: loss 23.207378
iteration 500 / 1500: loss 26.508271
iteration 600 / 1500: loss 21.876520
iteration 700 / 1500: loss 21.939206
iteration 800 / 1500: loss 25.317959
iteration 900 / 1500: loss 20.630530
iteration 1000 / 1500: loss 17.127213
iteration 1100 / 1500: loss 24.405165
iteration 1200 / 1500: loss 22.283576
iteration 1300 / 1500: loss 19.566886
iteration 1400 / 1500: loss 23.296308
iteration 0 / 1500: loss 1559.950278
iteration 100 / 1500: loss 35.393304
iteration 200 / 1500: loss 30.696443
iteration 300 / 1500: loss 33.169852
iteration 400 / 1500: loss 33.120913
iteration 500 / 1500: loss 33.478191
iteration 600 / 1500: loss 30.326305
iteration 700 / 1500: loss 33.692889
iteration 800 / 1500: loss 21.271244
iteration 900 / 1500: loss 28.265025
iteration 1000 / 1500: loss 33.888470
iteration 1100 / 1500: loss 32.588642
iteration 1200 / 1500: loss 29.961906
iteration 1300 / 1500: loss 28.233321
iteration 1400 / 1500: loss 32.649200
iteration 0 / 1500: loss 3106.209593
iteration 100 / 1500: loss 57.929791
iteration 200 / 1500: loss 74.851623
iteration 300 / 1500: loss 74.540410
iteration 400 / 1500: loss 68.043354
iteration 500 / 1500: loss 69.429617
iteration 600 / 1500: loss 63.305850
iteration 700 / 1500: loss 69.456483
iteration 800 / 1500: loss 57.876450
iteration 900 / 1500: loss 80.029685
iteration 1000 / 1500: loss 79.673372
iteration 1100 / 1500: loss 62.802481
iteration 1200 / 1500: loss 50.718919
iteration 1300 / 1500: loss 84.401221
iteration 1400 / 1500: loss 71.439129
```

```
iteration 0 / 1500: loss 175.468803
iteration 100 / 1500: loss 357.794190
iteration 200 / 1500: loss 261.610384
iteration 300 / 1500: loss 323.961122
iteration 400 / 1500: loss 236.804339
iteration 500 / 1500: loss 292.767227
iteration 600 / 1500: loss 338.246575
iteration 700 / 1500: loss 226.032447
iteration 800 / 1500: loss 299.913841
iteration 900 / 1500: loss 254.660160
iteration 1000 / 1500: loss 319.197245
iteration 1100 / 1500: loss 337.491635
iteration 1200 / 1500: loss 316.946059
iteration 1300 / 1500: loss 255.065476
iteration 1400 / 1500: loss 273.845585
iteration 0 / 1500: loss 794.020799
iteration 100 / 1500: loss 394760373444917569637606845452629573632.000000
iteration 200 / 1500: loss 65250728125730312921006734546646144648794568635569337904854949036761808896.000000
iteration 300 / 1500: loss 10785422771244952920169465875972079667182283880673163883353989456808185081499303733577127478046744740840341504.000000
iteration 400 / 1500: loss 17827440044859599015512288964553478889689748498611930211521987021846815679408570247155771735372325175882804807919132831712186340592330991720202
24.000000
iteration 500 / 1500: loss 294673306085319224289054386261208929132185374662469537610624126093126208555044007110672164094361307631834414652763647652715653170153468964127176997496598581885987809344378900578304.000000
iteration 600 / 1500: loss 48707137480622005038372726138584070992796047611148100113388087691493879638662815440760993692773055000442162218708269072306470479108164989868720498729444972260726834281796386995680700894182750610075422519243279695872.000000
iteration 700 / 1500: loss 805089973392199721876645725743651278784676856174480449563981250757331442385178688239528472097565786072895009529997109548575469387190160507373948915980234832608473572482149694748882434308222412089708792544831739724783236841706512909376626538681938 7392.000000
iteration 800 / 1500: loss 133074924699593671724557873974615038306098689471134092033427898632001646439542643165713247595780479809501400232010997228236054419987904832010862589685600589912131414892180764058785897937613362917978810498622127545132469845246026473724501853022543095056943059526263434546062283252328 0384.000000
```

```
iteration 900 / 1500: loss inf
iteration 1000 / 1500: loss inf
iteration 1100 / 1500: loss inf
iteration 1200 / 1500: loss inf
iteration 1300 / 1500: loss inf
iteration 1400 / 1500: loss inf
iteration 0 / 1500: loss 1558.822219
iteration 100 / 1500: loss 4207798039246850533175537350026849985891957311066635763731
42106868468155142626588956421314858710732079466318172981599807488.000000
iteration 200 / 1500: loss 1086558597385951279432465208308215137742869207865414633594
6470231097929239192116128043930123319357489078210113821117363802970789296852882813544
4405728106485547781825596833872444495900574813216890258212345239910511389586702268223
8881250555199488.000000
iteration 300 / 1500: loss inf
iteration 400 / 1500: loss inf
iteration 500 / 1500: loss inf
```

/content/drive/MyDrive/CS6353/Assignments/assignment2/assignment2/cs6353/classifiers/
linear_svm.py:125: RuntimeWarning: overflow encountered in multiply
  dW += 2 * reg * W
/content/drive/MyDrive/CS6353/Assignments/assignment2/assignment2/cs6353/classifiers/
linear_classifier.py:70: RuntimeWarning: invalid value encountered in subtract
  self.W -= learning_rate * grad

```
iteration 600 / 1500: loss nan
iteration 700 / 1500: loss nan
iteration 800 / 1500: loss nan
iteration 900 / 1500: loss nan
iteration 1000 / 1500: loss nan
iteration 1100 / 1500: loss nan
iteration 1200 / 1500: loss nan
iteration 1300 / 1500: loss nan
iteration 1400 / 1500: loss nan
iteration 0 / 1500: loss 3071.075695
iteration 100 / 1500: loss 2182133309946366599253484069681885190785452080302820461479
7202861682346491760762762456234455162260005124946570008000177952981352557009769576134
2850588122872372114047619043797859518559655959724032.000000
iteration 200 / 1500: loss inf
iteration 300 / 1500: loss inf
```

/content/drive/MyDrive/CS6353/Assignments/assignment2/assignment2/cs6353/classifiers/
linear_svm.py:94: RuntimeWarning: invalid value encountered in subtract
  margins = np.maximum(0, scores - correct_class_scores + 1)

```
iteration 400 / 1500: loss nan
iteration 500 / 1500: loss nan
iteration 600 / 1500: loss nan
iteration 700 / 1500: loss nan
iteration 800 / 1500: loss nan
iteration 900 / 1500: loss nan
iteration 1000 / 1500: loss nan
iteration 1100 / 1500: loss nan
iteration 1200 / 1500: loss nan
iteration 1300 / 1500: loss nan
iteration 1400 / 1500: loss nan
lr 1.000000e-07 reg 5.000000e+03 train accuracy: 0.372122 val accuracy: 0.367000
lr 1.000000e-07 reg 2.500000e+04 train accuracy: 0.367551 val accuracy: 0.378000
lr 1.000000e-07 reg 5.000000e+04 train accuracy: 0.356694 val accuracy: 0.366000
lr 1.000000e-07 reg 1.000000e+05 train accuracy: 0.335776 val accuracy: 0.357000
lr 2.000000e-07 reg 5.000000e+03 train accuracy: 0.384673 val accuracy: 0.385000
lr 2.000000e-07 reg 2.500000e+04 train accuracy: 0.364837 val accuracy: 0.377000
lr 2.000000e-07 reg 5.000000e+04 train accuracy: 0.344490 val accuracy: 0.350000
lr 2.000000e-07 reg 1.000000e+05 train accuracy: 0.318592 val accuracy: 0.341000
lr 5.000000e-06 reg 5.000000e+03 train accuracy: 0.245184 val accuracy: 0.274000
lr 5.000000e-06 reg 2.500000e+04 train accuracy: 0.209959 val accuracy: 0.211000
lr 5.000000e-06 reg 5.000000e+04 train accuracy: 0.177551 val accuracy: 0.193000
lr 5.000000e-06 reg 1.000000e+05 train accuracy: 0.167510 val accuracy: 0.174000
lr 5.000000e-05 reg 5.000000e+03 train accuracy: 0.183265 val accuracy: 0.194000
lr 5.000000e-05 reg 2.500000e+04 train accuracy: 0.081184 val accuracy: 0.077000
lr 5.000000e-05 reg 5.000000e+04 train accuracy: 0.100265 val accuracy: 0.087000
lr 5.000000e-05 reg 1.000000e+05 train accuracy: 0.100265 val accuracy: 0.087000
best validation accuracy achieved during cross-validation: 0.385000
```

In [ ]:
```python
# Visualize the cross-validation results
import math
x_scatter = [math.log10(x[0]) for x in results]
y_scatter = [math.log10(x[1]) for x in results]

# plot training accuracy
marker_size = 100
colors = [results[x][0] for x in results]
plt.subplot(2, 1, 1)

# plt.scatter(x_scatter, y_scatter, marker_size, c=colors)
plt.scatter(x_scatter, y_scatter, marker_size, c=colors, cmap=plt.cm.coolwarm)


plt.colorbar()
plt.xlabel('log learning rate')
plt.ylabel('log regularization strength')
plt.title('CIFAR-10 training accuracy')

# plot validation accuracy
colors = [results[x][1] for x in results] # default size of markers is 20
plt.subplot(2, 1, 2)

# plt.scatter(x_scatter, y_scatter, marker_size, c=colors)
plt.scatter(x_scatter, y_scatter, marker_size, c=colors, cmap=plt.cm.coolwarm)


plt.colorbar()
plt.xlabel('log learning rate')
plt.ylabel('log regularization strength')
```

```python
plt.title('CIFAR-10 validation accuracy')
plt.show()
```

CIFAR-10 training accuracy

CIFAR-10 validation accuracy
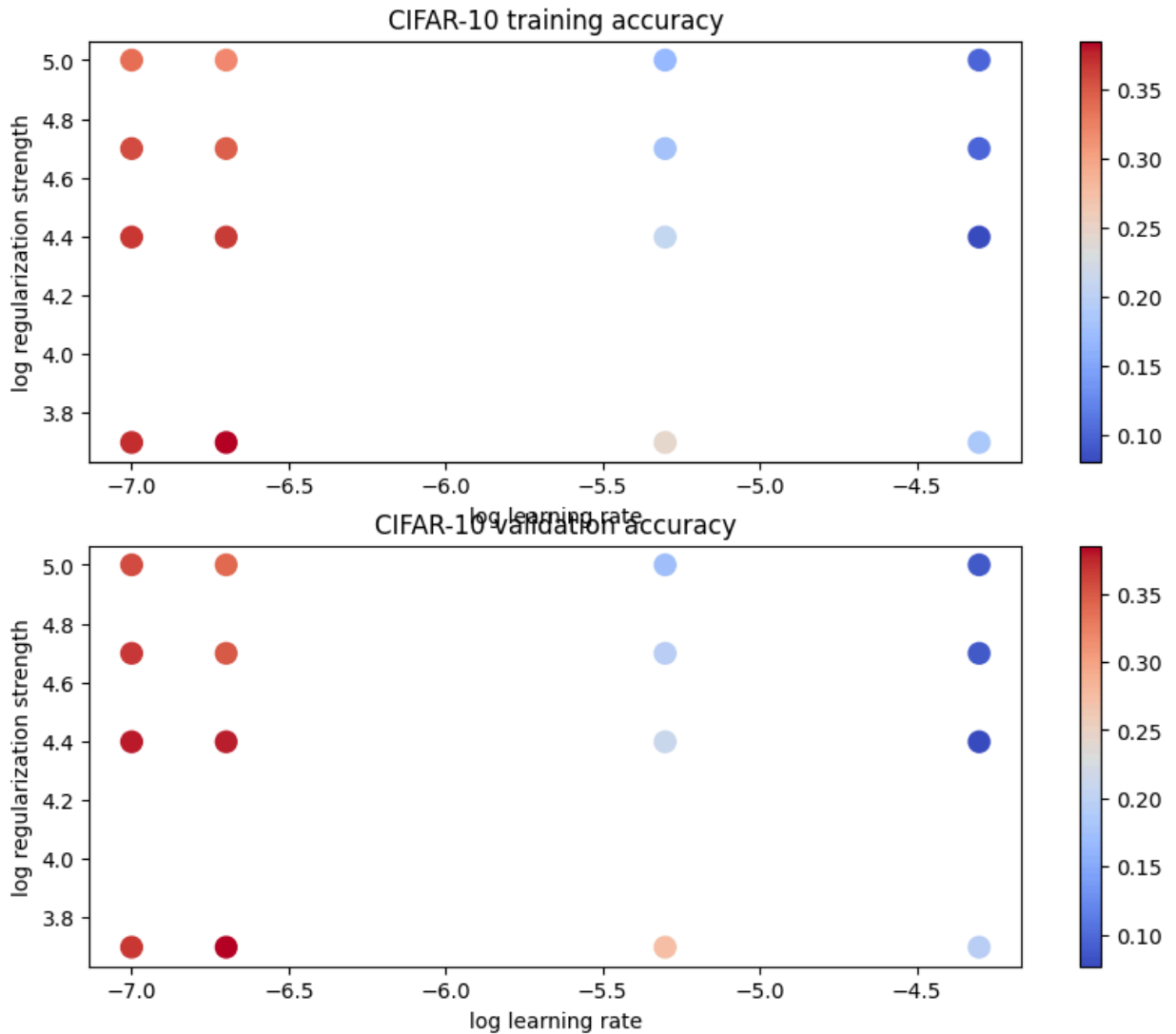

```python
# Evaluate the best svm on test set
y_test_pred = best_svm.predict(X_test)
test_accuracy = np.mean(y_test == y_test_pred)
print('linear SVM on raw pixels final test set accuracy: %f' % test_accuracy)
```

linear SVM on raw pixels final test set accuracy: 0.379000

```python
# Visualize the learned weights for each class.
# Depending on your choice of learning rate and regularization strength, these may
# or may not be nice to look at.
w = best_svm.W[:-1,:] # strip out the bias
w = w.reshape(32, 32, 3, 10)
w_min, w_max = np.min(w), np.max(w)
classes = ['plane', 'car', 'bird', 'cat', 'deer', 'dog', 'frog', 'horse', 'ship', 'tru
for i in range(10):
    plt.subplot(2, 5, i + 1)

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

plane   car   bird   cat   deer

dog   frog   horse   ship   truck
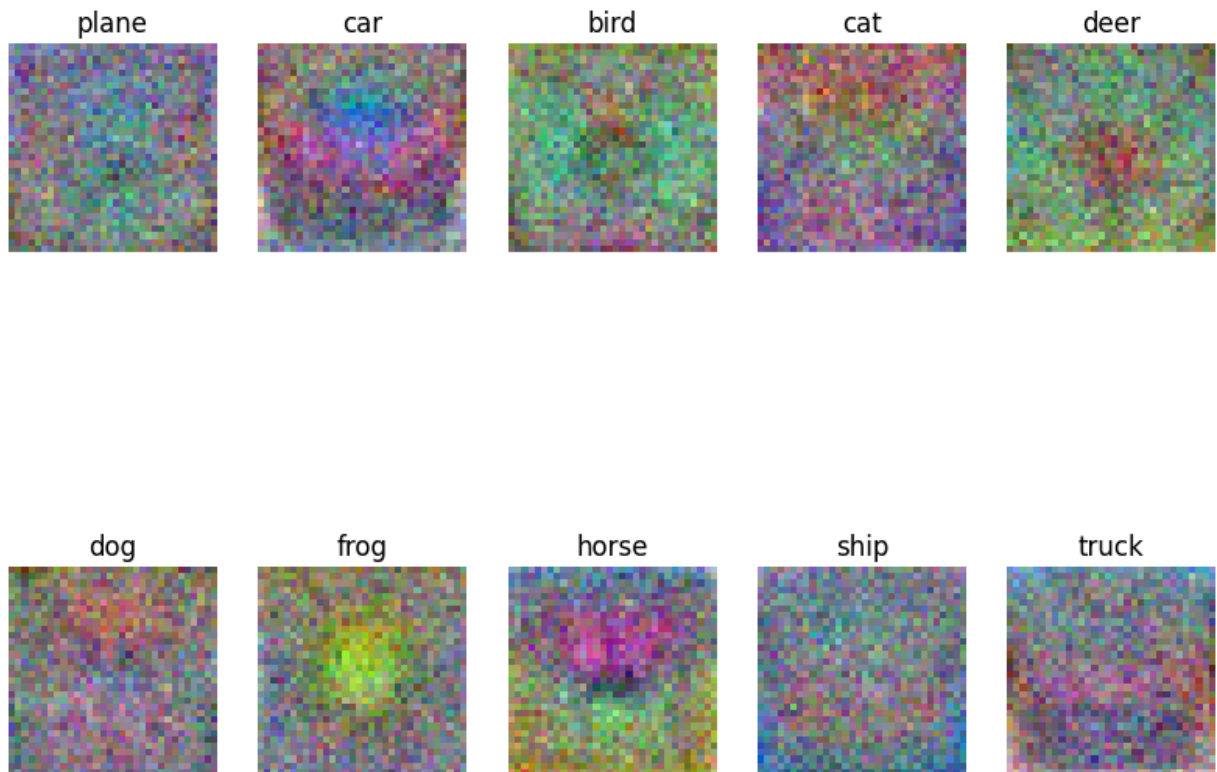
Inline question 2:

Describe what your visualized SVM weights look like, and offer a brief explanation for why they look the way that they do.

Your answer: The visualized SVM weights act as templates for each class, learned from the patterns in the training data. These weights represent the core features that define the images belonging to each class. When classifying a test image, SVM computes the inner product between the test image and each class's template. This inner product measures how closely the test image aligns with the learned features of each class, helping determine which class the image most likely belongs to. For instance, an frog is usually green in colour, hence the image shows a big green circle in the centre.

```python
In [ ]:  # 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/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/$FOLDERNAME/cs6353/datasets/
         !bash get_datasets.sh
         %cd /content/drive/My\ Drive/$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/assignment2/cs6353/datasets
--2024-09-29 20:45:04--  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'

cifar-10-python.tar 100%[===================>] 162.60M  40.6MB/s    in 4.2s

2024-09-29 20:45:08 (38.6 MB/s) - 'cifar-10-python.tar.gz' saved [170498071/17049807
1]


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/assignment2
Requirement already satisfied: anyio==3.7.1 in /usr/local/lib/python3.10/dist-package
s (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//colab_
requirements.txt (line 1)) (3.7.1)
Collecting appnope==0.1.3 (from -r /content/drive/My Drive/CS6353/Assignments/assignm
ent2/assignment2//colab_requirements.txt (line 2))
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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/assignment
2//colab_requirements.txt (line 3)) (23.1.0)
Requirement already satisfied: argon2-cffi-bindings==21.2.0 in /usr/local/lib/python
3.10/dist-packages (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/as
signment2//colab_requirements.txt (line 4)) (21.2.0)
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t2/assignment2//colab_requirements.txt (line 5))
  Downloading arrow-1.2.3-py3-none-any.whl.metadata (6.9 kB)
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nment2/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/assig
nment2/assignment2//colab_requirements.txt (line 7))
  Downloading async_lru-2.0.4-py3-none-any.whl.metadata (4.5 kB)
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nt2/assignment2//colab_requirements.txt (line 8))
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Requirement already satisfied: backcall==0.2.0 in /usr/local/lib/python3.10/dist-pack
ages (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//col
ab_requirements.txt (line 10)) (0.2.0)
Collecting beautifulsoup4==4.12.2 (from -r /content/drive/My Drive/CS6353/Assignment
s/assignment2/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/assignme
nt2/assignment2//colab_requirements.txt (line 12))
  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/ass
ignment2/assignment2//colab_requirements.txt (line 13))
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t2/assignment2//colab_requirements.txt (line 14))
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metadata (1.1 kB)
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nts/assignment2/assignment2//colab_requirements.txt (line 15))
  Downloading charset_normalizer-3.2.0-cp310-cp310-manylinux_2_17_x86_64.manylinux201
4_x86_64.whl.metadata (31 kB)
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2/assignment2//colab_requirements.txt (line 16))
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nment2/assignment2//colab_requirements.txt (line 17))
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whl.metadata (5.7 kB)
Collecting cycler==0.11.0 (from -r /content/drive/My Drive/CS6353/Assignments/assignm
ent2/assignment2//colab_requirements.txt (line 18))
  Downloading cycler-0.11.0-py3-none-any.whl.metadata (785 bytes)
Collecting debugpy==1.6.7.post1 (from -r /content/drive/My Drive/CS6353/Assignments/a
ssignment2/assignment2//colab_requirements.txt (line 19))
  Downloading debugpy-1.6.7.post1-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86
_64.whl.metadata (1.1 kB)
Requirement already satisfied: decorator<=5.0 in /usr/local/lib/python3.10/dist-packa
ges (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//cola
b_requirements.txt (line 20)) (4.4.2)
Requirement already satisfied: defusedxml==0.7.1 in /usr/local/lib/python3.10/dist-pa
ckages (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//c
olab_requirements.txt (line 21)) (0.7.1)
Collecting executing==1.2.0 (from -r /content/drive/My Drive/CS6353/Assignments/assig
nment2/assignment2//colab_requirements.txt (line 22))
  Downloading executing-1.2.0-py2.py3-none-any.whl.metadata (8.9 kB)
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s/assignment2/assignment2//colab_requirements.txt (line 23))
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gnment2/assignment2//colab_requirements.txt (line 24))
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4.whl.metadata (150 kB)
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2/assignment2//colab_requirements.txt (line 25))
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ment2/assignment2//colab_requirements.txt (line 27))
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Requirement already satisfied: ipykernel<=5.5.6 in /usr/local/lib/python3.10/dist-pac
kages (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//co
lab_requirements.txt (line 28)) (5.5.6)
Requirement already satisfied: ipython<=7.34.0 in /usr/local/lib/python3.10/dist-pack
ages (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//col
ab_requirements.txt (line 29)) (7.34.0)
Collecting isoduration==20.11.0 (from -r /content/drive/My Drive/CS6353/Assignments/a
ssignment2/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/assignmen
t2/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/assignme
nt2/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/assignme
nt2/assignment2//colab_requirements.txt (line 33))
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nment2/assignment2//colab_requirements.txt (line 34))
  Downloading jsonpointer-2.4-py2.py3-none-any.whl.metadata (2.5 kB)
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ignment2/assignment2//colab_requirements.txt (line 35))
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3/Assignments/assignment2/assignment2//colab_requirements.txt (line 36))
  Downloading jsonschema_specifications-2023.7.1-py3-none-any.whl.metadata (2.8 kB)
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assignment2/assignment2//colab_requirements.txt (line 37))
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ignment2/assignment2//colab_requirements.txt (line 38))
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Requirement already satisfied: jupyter_client<8.0 in /usr/local/lib/python3.10/dist-p
ackages (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//
colab_requirements.txt (line 39)) (6.1.12)
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signment2/assignment2//colab_requirements.txt (line 40))
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assignment2/assignment2//colab_requirements.txt (line 41))
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signments/assignment2/assignment2//colab_requirements.txt (line 42))
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gnment2/assignment2//colab_requirements.txt (line 43))
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ents/assignment2/assignment2//colab_requirements.txt (line 44))
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Collecting jupyterlab_server==2.24.0 (from -r /content/drive/My Drive/CS6353/Assignme
nts/assignment2/assignment2//colab_requirements.txt (line 45))
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gnment2/assignment2//colab_requirements.txt (line 46))
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4.whl.metadata (6.4 kB)
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gnment2/assignment2//colab_requirements.txt (line 47))
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4.whl.metadata (3.0 kB)
Collecting matplotlib==3.7.2 (from -r /content/drive/My Drive/CS6353/Assignments/assi
gnment2/assignment2//colab_requirements.txt (line 48))
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4.whl.metadata (5.6 kB)
Collecting matplotlib-inline==0.1.6 (from -r /content/drive/My Drive/CS6353/Assignmen
ts/assignment2/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/assignm
ent2/assignment2//colab_requirements.txt (line 50))
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Collecting nbclient==0.8.0 (from -r /content/drive/My Drive/CS6353/Assignments/assign
ment2/assignment2//colab_requirements.txt (line 51))
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nment2/assignment2//colab_requirements.txt (line 52))
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ment2/assignment2//colab_requirements.txt (line 53))
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signment2/assignment2//colab_requirements.txt (line 54))
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Collecting notebook_shim==0.2.3 (from -r /content/drive/My Drive/CS6353/Assignments/a
ssignment2/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 Drive/CS6353/Assignments/assi
gnment2/assignment2//colab_requirements.txt (line 56))
  Downloading numpy-1.23.5-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.wh
l.metadata (2.3 kB)
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nment2/assignment2//colab_requirements.txt (line 57))
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ment2/assignment2//colab_requirements.txt (line 58))
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Collecting pandas<=1.5.3 (from -r /content/drive/My Drive/CS6353/Assignments/assignme
nt2/assignment2//colab_requirements.txt (line 59))
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l.metadata (11 kB)
Collecting pandocfilters==1.5.0 (from -r /content/drive/My Drive/CS6353/Assignments/a
ssignment2/assignment2//colab_requirements.txt (line 60))
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Collecting parso==0.8.3 (from -r /content/drive/My Drive/CS6353/Assignments/assignmen
t2/assignment2//colab_requirements.txt (line 61))
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ent2/assignment2//colab_requirements.txt (line 62))
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Requirement already satisfied: pickleshare==0.7.5 in /usr/local/lib/python3.10/dist-p
ackages (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//
colab_requirements.txt (line 63)) (0.7.5)
Collecting Pillow==10.0.0 (from -r /content/drive/My Drive/CS6353/Assignments/assignm
ent2/assignment2//colab_requirements.txt (line 64))
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Collecting platformdirs==3.10.0 (from -r /content/drive/My Drive/CS6353/Assignments/a
ssignment2/assignment2//colab_requirements.txt (line 65))
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nts/assignment2/assignment2//colab_requirements.txt (line 66))
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s/assignment2/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-packag
es (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//colab
_requirements.txt (line 68)) (5.9.5)
Requirement already satisfied: ptyprocess==0.7.0 in /usr/local/lib/python3.10/dist-pa

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ckages (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//c
olab_requirements.txt (line 69)) (0.7.0)
Collecting pure-eval==0.2.2 (from -r /content/drive/My Drive/CS6353/Assignments/assig
nment2/assignment2//colab_requirements.txt (line 70))
  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/assign
ment2/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/assig
nment2/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/assig
nment2/assignment2//colab_requirements.txt (line 73))
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Requirement already satisfied: python-dateutil==2.8.2 in /usr/local/lib/python3.10/di
st-packages (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignmen
t2//colab_requirements.txt (line 74)) (2.8.2)
Collecting python-json-logger==2.0.7 (from -r /content/drive/My Drive/CS6353/Assignme
nts/assignment2/assignment2//colab_requirements.txt (line 75))
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t2/assignment2//colab_requirements.txt (line 76))
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nt2/assignment2//colab_requirements.txt (line 77))
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l.metadata (2.1 kB)
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rom -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//colab_requ
irements.txt (line 78)) (24.0.1)
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signment2/assignment2//colab_requirements.txt (line 79))
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Collecting requests==2.31.0 (from -r /content/drive/My Drive/CS6353/Assignments/assig
nment2/assignment2//colab_requirements.txt (line 80))
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Collecting rfc3339-validator==0.1.4 (from -r /content/drive/My Drive/CS6353/Assignmen
ts/assignment2/assignment2//colab_requirements.txt (line 81))
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ent2/assignment2//colab_requirements.txt (line 83))
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l.metadata (3.7 kB)
Collecting scipy==1.11.2 (from -r /content/drive/My Drive/CS6353/Assignments/assignme
nt2/assignment2//colab_requirements.txt (line 84))
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l.metadata (59 kB)
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Collecting seaborn==0.12.2 (from -r /content/drive/My Drive/CS6353/Assignments/assign
ment2/assignment2//colab_requirements.txt (line 85))
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gnment2/assignment2//colab_requirements.txt (line 86))
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Requirement already satisfied: six==1.16.0 in /usr/local/lib/python3.10/dist-packages
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quirements.txt (line 87)) (1.16.0)
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Collecting sniffio==1.3.0 (from -r /content/drive/My Drive/CS6353/Assignments/assignm
ent2/assignment2//colab_requirements.txt (line 88))
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nment2/assignment2//colab_requirements.txt (line 89))
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gnment2/assignment2//colab_requirements.txt (line 90))
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gnment2/assignment2//colab_requirements.txt (line 91))
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Collecting tinycss2==1.2.1 (from -r /content/drive/My Drive/CS6353/Assignments/assign
ment2/assignment2//colab_requirements.txt (line 92))
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Collecting tornado<=6.3.2 (from -r /content/drive/My Drive/CS6353/Assignments/assignm
ent2/assignment2//colab_requirements.txt (line 93))
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x_2_17_x86_64.manylinux2014_x86_64.whl.metadata (2.5 kB)
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Collecting tzdata==2023.3 (from -r /content/drive/My Drive/CS6353/Assignments/assignm
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signment2/assignment2//colab_requirements.txt (line 96))
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ent2/assignment2//colab_requirements.txt (line 97))
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Collecting wcwidth==0.2.6 (from -r /content/drive/My Drive/CS6353/Assignments/assignm
ent2/assignment2//colab_requirements.txt (line 98))
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ment2/assignment2//colab_requirements.txt (line 99))
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2//colab_requirements.txt (line 100)) (0.5.1)
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s/assignment2/assignment2//colab_requirements.txt (line 101))
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ges (from anyio==3.7.1->-r /content/drive/My Drive/CS6353/Assignments/assignment2/ass
ignment2//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/a
ssignment2/assignment2//colab_requirements.txt (line 7)) (4.12.2)
Collecting jupyter_client<8.0 (from -r /content/drive/My Drive/CS6353/Assignments/ass
ignment2/assignment2//colab_requirements.txt (line 39))
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jupyterlab==4.0.5->-r /content/drive/My Drive/CS6353/Assignments/assignment2/assignme
nt2//colab_requirements.txt (line 43)) (2.0.1)
Requirement already satisfied: ipython-genutils in /usr/local/lib/python3.10/dist-pac
kages (from ipykernel<=5.5.6->-r /content/drive/My Drive/CS6353/Assignments/assignmen
t2/assignment2//colab_requirements.txt (line 28)) (0.2.0)
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kages (from ipython<=7.34.0->-r /content/drive/My Drive/CS6353/Assignments/assignment

2/assignment2//colab_requirements.txt (line 29)) (71.0.4)
Requirement already satisfied: entrypoints in /usr/local/lib/python3.10/dist-packages
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ssignment2//colab_requirements.txt (line 39)) (0.4)
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Downloading referencing-0.30.2-py3-none-any.whl (25 kB)
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Downloading rfc3339_validator-0.1.4-py2.py3-none-any.whl (3.5 kB)
Downloading rfc3986_validator-0.1.1-py2.py3-none-any.whl (4.2 kB)
Downloading rpds_py-0.9.2-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.whl
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Downloading scipy-1.11.2-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.whl
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Downloading seaborn-0.12.2-py3-none-any.whl (293 kB)
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Downloading Send2Trash-1.8.2-py3-none-any.whl (18 kB)
Downloading sniffio-1.3.0-py3-none-any.whl (10 kB)
Downloading soupsieve-2.4.1-py3-none-any.whl (36 kB)
Downloading stack_data-0.6.2-py3-none-any.whl (24 kB)
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)
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Downloading tzdata-2023.3-py2.py3-none-any.whl (341 kB)
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Downloading uri_template-1.3.0-py3-none-any.whl (11 kB)
Downloading urllib3-2.0.4-py3-none-any.whl (123 kB)
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Downloading wcwidth-0.2.6-py2.py3-none-any.whl (29 kB)
Downloading webcolors-1.13-py3-none-any.whl (14 kB)
Downloading websocket_client-1.6.2-py3-none-any.whl (57 kB)
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Downloading jupyter_client-7.4.9-py3-none-any.whl (133 kB)
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Downloading numpy-1.23.5-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.whl
(17.1 MB)
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Downloading pandas-1.5.3-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.whl
(12.1 MB)
─────────────────────────────────────────────────── 12.1/12.1 MB 101.4 MB/s eta 0:00:00
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)
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Installing collected packages: wcwidth, pytz, pure-eval, json5, fastjsonschema, execu
ting, appnope, websocket-client, webcolors, urllib3, uri-template, tzdata, traitlets,
tornado, tinycss2, soupsieve, sniffio, Send2Trash, rpds-py, rfc3986-validator, rfc333
9-validator, PyYAML, python-json-logger, pyparsing, Pygments, pycparser, prompt-toolk
it, prometheus-client, platformdirs, Pillow, pexpect, parso, pandocfilters, packagin
g, overrides, numpy, nest-asyncio, mistune, MarkupSafe, kiwisolver, jupyterlab-pygmen
ts, jsonpointer, idna, fqdn, fonttools, debugpy, cycler, charset-normalizer, certifi,
bleach, Babel, attrs, async-lru, asttokens, terminado, stack-data, scipy, requests, r
eferencing, pandas, matplotlib-inline, jupyter_core, Jinja2, jedi, imageio, contourp
y, comm, cffi, beautifulsoup4, arrow, matplotlib, jupyter_server_terminals, jupyter_c
lient, jsonschema-specifications, isoduration, seaborn, jsonschema, nbformat, nbclien
t, jupyter-events, nbconvert, jupyter_server, notebook_shim, jupyterlab_server, jupyt
er-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 2.20.0
    Uninstalling fastjsonschema-2.20.0:
      Successfully uninstalled fastjsonschema-2.20.0
  Attempting uninstall: websocket-client
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                       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 24.8.0
                       Uninstalling webcolors-24.8.0:
                          Successfully uninstalled webcolors-24.8.0
                    Attempting uninstall: urllib3
                       Found existing installation: urllib3 2.2.3
                       Uninstalling urllib3-2.2.3:
                          Successfully uninstalled urllib3-2.2.3
                    Attempting uninstall: tzdata
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                          Successfully uninstalled tzdata-2024.1
                    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
                       Uninstalling tornado-6.3.3:
                          Successfully uninstalled tornado-6.3.3
                    Attempting uninstall: tinycss2
                       Found existing installation: tinycss2 1.3.0
                       Uninstalling tinycss2-1.3.0:
                          Successfully uninstalled tinycss2-1.3.0
                    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 0.20.0
                       Uninstalling rpds-py-0.20.0:
                          Successfully uninstalled rpds-py-0.20.0
                    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 3.1.4
                       Uninstalling pyparsing-3.1.4:
                          Successfully uninstalled pyparsing-3.1.4
                    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
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          Found existing installation: prompt_toolkit 3.0.47
          Uninstalling prompt_toolkit-3.0.47:
            Successfully uninstalled prompt_toolkit-3.0.47
        Attempting uninstall: prometheus-client
          Found existing installation: prometheus_client 0.21.0
          Uninstalling prometheus_client-0.21.0:
            Successfully uninstalled prometheus_client-0.21.0
        Attempting uninstall: platformdirs
          Found existing installation: platformdirs 4.3.6
          Uninstalling platformdirs-4.3.6:
            Successfully uninstalled platformdirs-4.3.6
        Attempting uninstall: Pillow
          Found existing installation: pillow 10.4.0
          Uninstalling pillow-10.4.0:
            Successfully uninstalled pillow-10.4.0
        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 24.1
          Uninstalling packaging-24.1:
            Successfully uninstalled packaging-24.1
        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 0.8.4
          Uninstalling mistune-0.8.4:
            Successfully uninstalled mistune-0.8.4
        Attempting uninstall: MarkupSafe
          Found existing installation: MarkupSafe 2.1.5
          Uninstalling MarkupSafe-2.1.5:
            Successfully uninstalled MarkupSafe-2.1.5
        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: idna
          Found existing installation: idna 3.10
          Uninstalling idna-3.10:
            Successfully uninstalled idna-3.10
        Attempting uninstall: fonttools
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       Found existing installation: fonttools 4.53.1
       Uninstalling fonttools-4.53.1:
         Successfully uninstalled fonttools-4.53.1
     Attempting uninstall: debugpy
       Found existing installation: debugpy 1.6.6
       Uninstalling debugpy-1.6.6:
         Successfully uninstalled debugpy-1.6.6
     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 3.3.2
       Uninstalling charset-normalizer-3.3.2:
         Successfully uninstalled charset-normalizer-3.3.2
     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 6.1.0
       Uninstalling bleach-6.1.0:
         Successfully uninstalled bleach-6.1.0
     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 2.1.4
       Uninstalling pandas-2.1.4:
         Successfully uninstalled pandas-2.1.4
     Attempting uninstall: matplotlib-inline
       Found existing installation: matplotlib-inline 0.1.7
       Uninstalling matplotlib-inline-0.1.7:
         Successfully uninstalled matplotlib-inline-0.1.7
     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
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        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 2.35.1
        Uninstalling imageio-2.35.1:
          Successfully uninstalled imageio-2.35.1
      Attempting uninstall: contourpy
        Found existing installation: contourpy 1.3.0
        Uninstalling contourpy-1.3.0:
          Successfully uninstalled contourpy-1.3.0
      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 3.7.1
        Uninstalling matplotlib-3.7.1:
          Successfully uninstalled matplotlib-3.7.1
      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 2023.12.1
        Uninstalling jsonschema-specifications-2023.12.1:
          Successfully uninstalled jsonschema-specifications-2023.12.1
      Attempting uninstall: seaborn
        Found existing installation: seaborn 0.13.1
        Uninstalling seaborn-0.13.1:
          Successfully uninstalled seaborn-0.13.1
      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 0.10.0
        Uninstalling nbclient-0.10.0:
          Successfully uninstalled nbclient-0.10.0
      Attempting uninstall: nbconvert
        Found existing installation: nbconvert 6.5.4
        Uninstalling nbconvert-6.5.4:
          Successfully uninstalled nbconvert-6.5.4
      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 package
```

```
s that are installed. This behaviour is the source of the following dependency confli
cts.
albucore 0.0.16 requires numpy>=1.24, but you have numpy 1.23.5 which is incompatibl
e.
albumentations 1.4.15 requires numpy>=1.24.4, but you have numpy 1.23.5 which is inco
mpatible.
bigframes 1.18.0 requires numpy>=1.24.0, but you have numpy 1.23.5 which is incompati
ble.
bokeh 3.4.3 requires contourpy>=1.2, but you have contourpy 1.1.0 which is incompatib
le.
chex 0.1.86 requires numpy>=1.24.1, but you have numpy 1.23.5 which is incompatible.
cudf-cu12 24.4.1 requires pandas<2.2.2dev0,>=2.0, but you have pandas 1.5.3 which is
incompatible.
google-colab 1.0.0 requires pandas==2.1.4, but you have pandas 1.5.3 which is incompa
tible.
google-colab 1.0.0 requires requests==2.32.3, but you have requests 2.31.0 which is i
ncompatible.
google-colab 1.0.0 requires tornado==6.3.3, but you have tornado 6.3.2 which is incom
patible.
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.
mizani 0.11.4 requires pandas>=2.1.0, but you have pandas 1.5.3 which is incompatibl
e.
pandas-stubs 2.1.4.231227 requires numpy>=1.26.0; python_version < "3.13", but you ha
ve numpy 1.23.5 which is incompatible.
plotnine 0.13.6 requires pandas<3.0.0,>=2.1.0, but you have pandas 1.5.3 which is inc
ompatible.
scikit-image 0.24.0 requires imageio>=2.33, but you have imageio 2.31.1 which is inco
mpatible.
xarray 2024.9.0 requires numpy>=1.24, but you have numpy 1.23.5 which is incompatibl
e.
xarray 2024.9.0 requires pandas>=2.1, but you have pandas 1.5.3 which is incompatibl
e.
Successfully installed Babel-2.12.1 Jinja2-3.1.2 MarkupSafe-2.1.3 Pillow-10.0.0 PyYAM
L-6.0.1 Pygments-2.16.1 Send2Trash-1.8.2 appnope-0.1.3 arrow-1.2.3 asttokens-2.2.1 as
ync-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 im
ageio-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 jupy
ter_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 platfor
mdirs-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 request
s-2.31.0 rfc3339-validator-0.1.4 rfc3986-validator-0.1.1 rpds-py-0.9.2 scipy-1.11.2 s
eaborn-0.12.2 sniffio-1.3.0 soupsieve-2.4.1 stack-data-0.6.2 terminado-0.17.1 tinycss
2-1.2.1 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
```

Softmax 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.

This exercise is analogous to the SVM exercise. You will:

- implement a fully-vectorized **loss function** for the Softmax classifier
- implement the fully-vectorized expression for its **analytic gradient**
- **check your implementation** with numerical gradient
- use a validation set to **tune the learning rate and regularization** strength
- **optimize** the loss function with **SGD**
- **visualize** the final learned weights

```python
In [ ]: 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 external modules
        # see http://stackoverflow.com/questions/1907993/autoreload-of-modules-in-ipython
        %load_ext autoreload
        %autoreload 2
```

```python
In [ ]: def get_CIFAR10_data(num_training=49000, num_validation=1000, num_test=1000, num_dev=5
            """
            Load the CIFAR-10 dataset from disk and perform preprocessing to prepare
            it for the linear classifier. These are the same steps as we used for the
            SVM, but condensed to a single function.
            """
            # Load the raw CIFAR-10 data
            cifar10_dir = 'cs6353/datasets/cifar-10-batches-py'

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

            # subsample the data
            mask = list(range(num_training, num_training + num_validation))
            X_val = X_train[mask]
            y_val = y_train[mask]
            mask = list(range(num_training))
            X_train = X_train[mask]
            y_train = y_train[mask]
            mask = list(range(num_test))
            X_test = X_test[mask]
            y_test = y_test[mask]
            mask = np.random.choice(num_training, num_dev, replace=False)
            X_dev = X_train[mask]
            y_dev = y_train[mask]

            # Preprocessing: reshape the image data into rows
            X_train = np.reshape(X_train, (X_train.shape[0], -1))
            X_val = np.reshape(X_val, (X_val.shape[0], -1))
            X_test = np.reshape(X_test, (X_test.shape[0], -1))
            X_dev = np.reshape(X_dev, (X_dev.shape[0], -1))
```

```
    # Normalize the data: subtract the mean image
    mean_image = np.mean(X_train, axis = 0)
    X_train -= mean_image
    X_val -= mean_image
    X_test -= mean_image
    X_dev -= mean_image

    # add bias dimension and transform into columns
    X_train = np.hstack([X_train, np.ones((X_train.shape[0], 1))])
    X_val = np.hstack([X_val, np.ones((X_val.shape[0], 1))])
    X_test = np.hstack([X_test, np.ones((X_test.shape[0], 1))])
    X_dev = np.hstack([X_dev, np.ones((X_dev.shape[0], 1))])

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


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

# Invoke the above function to get our data.
X_train, y_train, X_val, y_val, X_test, y_test, X_dev, y_dev = get_CIFAR10_data()
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)
print('dev data shape: ', X_dev.shape)
print('dev labels shape: ', y_dev.shape)
```

```
Train data shape:  (49000, 3073)
Train labels shape:  (49000,)
Validation data shape:  (1000, 3073)
Validation labels shape:  (1000,)
Test data shape:  (1000, 3073)
Test labels shape:  (1000,)
dev data shape:  (500, 3073)
dev labels shape:  (500,)
```

Softmax Classifier

Your code for this section will all be written inside **cs6353/classifiers/softmax.py**.

```
In [ ]:  # First implement the naive softmax loss function with nested loops.
         # Open the file cs6353/classifiers/softmax.py and implement the
         # softmax_loss_naive function.

         from cs6353.classifiers.softmax import softmax_loss_naive
         import time

         # Generate a random softmax weight matrix and use it to compute the loss.
         W = np.random.randn(3073, 10) * 0.0001
```

```
loss, grad = softmax_loss_naive(W, X_dev, y_dev, 0.0)

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

```
loss: 2.372274
sanity check: 2.302585
```

Inline Question 1:

Why do we expect our loss to be close to -log(0.1)? Explain briefly.**

Your answer: We expect the initial loss to be close to -log(0.1) because, at the start, before any learning has occurred, the weights are randomly initialized. This randomness means the model has no prior knowledge, so it treats all classes as equally likely. Since CIFAR-10 has ten possible classes, the probability assigned to each class is 1 / 10 = 0.1. The softmax loss is calculated as the negative log of the probability assigned to the correct class. Therefore, with all classes equally probable, the initial loss will approximate -log(0.1). Note: Weights are initialized as small random values to break symmetry between neurons, therby ensuring diverse feature learning, and prevent issues like vanishing or exploding gradients and stabilizing the training process.

```
In [ ]:  # Complete the implementation of softmax_loss_naive and implement a (naive)
         # version of the gradient that uses nested loops.
         loss, grad = softmax_loss_naive(W, X_dev, y_dev, 0.0)

         # As we did for the SVM, use numeric gradient checking as a debugging tool.
         # The numeric gradient should be close to the analytic gradient.
         from cs6353.gradient_check import grad_check_sparse
         f = lambda w: softmax_loss_naive(w, X_dev, y_dev, 0.0)[0]
         grad_numerical = grad_check_sparse(f, W, grad, 10)

         # similar to SVM case, do another gradient check with regularization
         loss, grad = softmax_loss_naive(W, X_dev, y_dev, 5e1)
         f = lambda w: softmax_loss_naive(w, X_dev, y_dev, 5e1)[0]
         grad_numerical = grad_check_sparse(f, W, grad, 10)
```

```
numerical: -0.371995 analytic: -0.371995, relative error: 9.412997e-08
numerical: 0.061519 analytic: 0.061519, relative error: 3.447618e-07
numerical: 0.015320 analytic: 0.015319, relative error: 3.233951e-06
numerical: -3.687516 analytic: -3.687516, relative error: 1.263554e-08
numerical: 0.483787 analytic: 0.483787, relative error: 2.404416e-08
numerical: 2.102420 analytic: 2.102420, relative error: 3.515781e-08
numerical: 0.204487 analytic: 0.204487, relative error: 3.160889e-08
numerical: 0.191245 analytic: 0.191245, relative error: 1.395001e-07
numerical: 1.774520 analytic: 1.774520, relative error: 6.925438e-09
numerical: 1.360575 analytic: 1.360575, relative error: 1.581803e-08
numerical: 0.061908 analytic: 0.061908, relative error: 1.201088e-06
numerical: -1.212397 analytic: -1.212397, relative error: 4.147778e-10
numerical: -2.129776 analytic: -2.129776, relative error: 3.312535e-09
numerical: -1.419020 analytic: -1.419020, relative error: 2.004402e-08
numerical: -0.530724 analytic: -0.530724, relative error: 2.532679e-08
numerical: 0.915288 analytic: 0.915288, relative error: 7.900550e-08
numerical: -1.146401 analytic: -1.146401, relative error: 7.418738e-09
numerical: 0.464515 analytic: 0.464515, relative error: 3.568645e-08
numerical: 2.546614 analytic: 2.546614, relative error: 1.194214e-09
numerical: 2.900167 analytic: 2.900167, relative error: 2.507992e-08
```

In [ ]:
```python
# Now that we have a naive implementation of the softmax loss function and its gradien
# implement a vectorized version in softmax_loss_vectorized.
# The two versions should compute the same results, but the vectorized version should
# much faster.
tic = time.time()
loss_naive, grad_naive = softmax_loss_naive(W, X_dev, y_dev, 0.000005)
toc = time.time()
print('naive loss: %e computed in %fs' % (loss_naive, toc - tic))

from cs6353.classifiers.softmax import softmax_loss_vectorized
tic = time.time()
loss_vectorized, grad_vectorized = softmax_loss_vectorized(W, X_dev, y_dev, 0.000005)
toc = time.time()
print('vectorized loss: %e computed in %fs' % (loss_vectorized, toc - tic))

# As we did for the SVM, we use the Frobenius norm to compare the two versions
# of the gradient.
grad_difference = np.linalg.norm(grad_naive - grad_vectorized, ord='fro')
print('Loss difference: %f' % np.abs(loss_naive - loss_vectorized))
print('Gradient difference: %f' % grad_difference)
```

```
naive loss: 2.372274e+00 computed in 0.079418s
vectorized loss: 2.372274e+00 computed in 0.009491s
Loss difference: 0.000000
Gradient difference: 0.000000
```

In [ ]:
```python
# Use the validation set to tune hyperparameters (regularization strength and
# learning rate). You should experiment with different ranges for the learning
# rates and regularization strengths; if you are careful you should be able to
# get a classification accuracy of over 0.35 on the validation set.
from cs6353.classifiers import Softmax
results = {}
best_val = -1
best_softmax = None
learning_rates = [1e-7, 5e-7, 2e-6, 1e-5]
regularization_strengths = [2.5e4, 5e4, 1e3, 5e3, 5e2]

################################################################################
# TODO:                                                                        #
```

```python
    # 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 softmax classifier in best_softmax.                          #
    ################################################################################
    for lr in learning_rates:
        for reg in regularization_strengths:

            softmax = Softmax()

            softmax.train(X_train, y_train, learning_rate=lr, reg=reg, num_iters=1500, ver

            y_train_pred = softmax.predict(X_train)
            y_val_pred = softmax.predict(X_val)

            train_results = y_train_pred == y_train
            y_train_accuracy = np.mean(train_results)

            val_results = y_val_pred == y_val
            y_val_accuracy = np.mean(val_results)

            results[(lr, reg)] = (y_train_accuracy, y_val_accuracy)

            if y_val_accuracy > best_val:
                best_val = y_val_accuracy
                best_softmax = softmax
    ################################################################################
    #                              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)
```

```
iteration 0 / 1500: loss 773.286769
iteration 100 / 1500: loss 283.934386
iteration 200 / 1500: loss 105.170970
iteration 300 / 1500: loss 39.787913
iteration 400 / 1500: loss 15.907862
iteration 500 / 1500: loss 7.166709
iteration 600 / 1500: loss 3.905783
iteration 700 / 1500: loss 2.791000
iteration 800 / 1500: loss 2.311611
iteration 900 / 1500: loss 2.217738
iteration 1000 / 1500: loss 2.140678
iteration 1100 / 1500: loss 2.090252
iteration 1200 / 1500: loss 2.083181
iteration 1300 / 1500: loss 2.053110
iteration 1400 / 1500: loss 2.066172
iteration 0 / 1500: loss 1543.696962
iteration 100 / 1500: loss 207.893923
iteration 200 / 1500: loss 29.661242
iteration 300 / 1500: loss 5.796347
iteration 400 / 1500: loss 2.656400
iteration 500 / 1500: loss 2.273789
iteration 600 / 1500: loss 2.124694
iteration 700 / 1500: loss 2.139541
iteration 800 / 1500: loss 2.106462
iteration 900 / 1500: loss 2.160759
iteration 1000 / 1500: loss 2.132417
iteration 1100 / 1500: loss 2.215994
iteration 1200 / 1500: loss 2.163452
iteration 1300 / 1500: loss 2.149876
iteration 1400 / 1500: loss 2.179613
iteration 0 / 1500: loss 35.893486
iteration 100 / 1500: loss 32.765418
iteration 200 / 1500: loss 31.312471
iteration 300 / 1500: loss 30.108250
iteration 400 / 1500: loss 28.743104
iteration 500 / 1500: loss 27.463748
iteration 600 / 1500: loss 26.465778
iteration 700 / 1500: loss 25.412667
iteration 800 / 1500: loss 24.465364
iteration 900 / 1500: loss 23.400351
iteration 1000 / 1500: loss 22.508864
iteration 1100 / 1500: loss 21.670981
iteration 1200 / 1500: loss 20.891951
iteration 1300 / 1500: loss 20.073908
iteration 1400 / 1500: loss 19.151124
iteration 0 / 1500: loss 158.049696
iteration 100 / 1500: loss 128.967762
iteration 200 / 1500: loss 105.296711
iteration 300 / 1500: loss 86.157547
iteration 400 / 1500: loss 70.556245
iteration 500 / 1500: loss 58.019514
iteration 600 / 1500: loss 47.716924
iteration 700 / 1500: loss 39.324780
iteration 800 / 1500: loss 32.433260
iteration 900 / 1500: loss 26.893101
iteration 1000 / 1500: loss 22.486907
iteration 1100 / 1500: loss 18.680364
iteration 1200 / 1500: loss 15.671470
iteration 1300 / 1500: loss 13.132092
iteration 1400 / 1500: loss 11.007521
```

```
iteration 0 / 1500: loss 20.652732
iteration 100 / 1500: loss 18.925048
iteration 200 / 1500: loss 18.339368
iteration 300 / 1500: loss 17.785633
iteration 400 / 1500: loss 17.466845
iteration 500 / 1500: loss 16.904538
iteration 600 / 1500: loss 16.579248
iteration 700 / 1500: loss 16.011571
iteration 800 / 1500: loss 15.673991
iteration 900 / 1500: loss 15.689790
iteration 1000 / 1500: loss 14.933817
iteration 1100 / 1500: loss 14.834838
iteration 1200 / 1500: loss 14.601856
iteration 1300 / 1500: loss 14.468670
iteration 1400 / 1500: loss 13.879115
iteration 0 / 1500: loss 777.467621
iteration 100 / 1500: loss 6.949041
iteration 200 / 1500: loss 2.083277
iteration 300 / 1500: loss 2.119934
iteration 400 / 1500: loss 2.136920
iteration 500 / 1500: loss 2.031330
iteration 600 / 1500: loss 2.079533
iteration 700 / 1500: loss 2.079301
iteration 800 / 1500: loss 2.102427
iteration 900 / 1500: loss 2.085512
iteration 1000 / 1500: loss 2.094594
iteration 1100 / 1500: loss 2.042750
iteration 1200 / 1500: loss 2.080415
iteration 1300 / 1500: loss 2.076107
iteration 1400 / 1500: loss 2.092127
iteration 0 / 1500: loss 1539.462798
iteration 100 / 1500: loss 2.153548
iteration 200 / 1500: loss 2.146392
iteration 300 / 1500: loss 2.165555
iteration 400 / 1500: loss 2.166985
iteration 500 / 1500: loss 2.162476
iteration 600 / 1500: loss 2.193160
iteration 700 / 1500: loss 2.163300
iteration 800 / 1500: loss 2.129586
iteration 900 / 1500: loss 2.129412
iteration 1000 / 1500: loss 2.115654
iteration 1100 / 1500: loss 2.134502
iteration 1200 / 1500: loss 2.102968
iteration 1300 / 1500: loss 2.127808
iteration 1400 / 1500: loss 2.226821
iteration 0 / 1500: loss 35.501322
iteration 100 / 1500: loss 27.612282
iteration 200 / 1500: loss 22.562517
iteration 300 / 1500: loss 18.818199
iteration 400 / 1500: loss 15.430590
iteration 500 / 1500: loss 12.816506
iteration 600 / 1500: loss 10.901668
iteration 700 / 1500: loss 9.128906
iteration 800 / 1500: loss 7.884038
iteration 900 / 1500: loss 6.714170
iteration 1000 / 1500: loss 5.821408
iteration 1100 / 1500: loss 5.056165
iteration 1200 / 1500: loss 4.431106
iteration 1300 / 1500: loss 3.907053
iteration 1400 / 1500: loss 3.493153
```

```
iteration 0 / 1500: loss 158.162174
iteration 100 / 1500: loss 58.253360
iteration 200 / 1500: loss 22.436421
iteration 300 / 1500: loss 9.343721
iteration 400 / 1500: loss 4.637779
iteration 500 / 1500: loss 2.901247
iteration 600 / 1500: loss 2.307660
iteration 700 / 1500: loss 2.058771
iteration 800 / 1500: loss 1.982710
iteration 900 / 1500: loss 1.927678
iteration 1000 / 1500: loss 1.953555
iteration 1100 / 1500: loss 1.976973
iteration 1200 / 1500: loss 1.939448
iteration 1300 / 1500: loss 1.940863
iteration 1400 / 1500: loss 1.954266
iteration 0 / 1500: loss 21.491128
iteration 100 / 1500: loss 16.757458
iteration 200 / 1500: loss 15.018785
iteration 300 / 1500: loss 13.555854
iteration 400 / 1500: loss 12.307013
iteration 500 / 1500: loss 11.443112
iteration 600 / 1500: loss 10.282914
iteration 700 / 1500: loss 9.279587
iteration 800 / 1500: loss 8.794230
iteration 900 / 1500: loss 7.919453
iteration 1000 / 1500: loss 7.484387
iteration 1100 / 1500: loss 6.655847
iteration 1200 / 1500: loss 6.308657
iteration 1300 / 1500: loss 5.885525
iteration 1400 / 1500: loss 5.568216
iteration 0 / 1500: loss 769.357716
iteration 100 / 1500: loss 2.144909
iteration 200 / 1500: loss 2.108287
iteration 300 / 1500: loss 2.105363
iteration 400 / 1500: loss 2.093852
iteration 500 / 1500: loss 2.084866
iteration 600 / 1500: loss 2.105764
iteration 700 / 1500: loss 2.132362
iteration 800 / 1500: loss 2.190142
iteration 900 / 1500: loss 2.079856
iteration 1000 / 1500: loss 2.157157
iteration 1100 / 1500: loss 2.036852
iteration 1200 / 1500: loss 2.101459
iteration 1300 / 1500: loss 2.172632
iteration 1400 / 1500: loss 2.080623
iteration 0 / 1500: loss 1568.986020
iteration 100 / 1500: loss 2.130005
iteration 200 / 1500: loss 2.195333
iteration 300 / 1500: loss 2.118576
iteration 400 / 1500: loss 2.110801
iteration 500 / 1500: loss 2.176147
iteration 600 / 1500: loss 2.180191
iteration 700 / 1500: loss 2.148134
iteration 800 / 1500: loss 2.194246
iteration 900 / 1500: loss 2.153384
iteration 1000 / 1500: loss 2.211938
iteration 1100 / 1500: loss 2.171286
iteration 1200 / 1500: loss 2.175800
iteration 1300 / 1500: loss 2.204375
iteration 1400 / 1500: loss 2.235376
```

```
iteration 0 / 1500: loss 35.780635
iteration 100 / 1500: loss 15.569537
iteration 200 / 1500: loss 7.900372
iteration 300 / 1500: loss 4.639468
iteration 400 / 1500: loss 3.027866
iteration 500 / 1500: loss 2.322064
iteration 600 / 1500: loss 2.108105
iteration 700 / 1500: loss 1.860409
iteration 800 / 1500: loss 1.904655
iteration 900 / 1500: loss 1.957582
iteration 1000 / 1500: loss 2.005855
iteration 1100 / 1500: loss 1.916817
iteration 1200 / 1500: loss 1.896621
iteration 1300 / 1500: loss 1.961342
iteration 1400 / 1500: loss 1.778122
iteration 0 / 1500: loss 157.822479
iteration 100 / 1500: loss 4.582862
iteration 200 / 1500: loss 2.079908
iteration 300 / 1500: loss 2.002190
iteration 400 / 1500: loss 1.981158
iteration 500 / 1500: loss 1.869947
iteration 600 / 1500: loss 2.040303
iteration 700 / 1500: loss 1.875580
iteration 800 / 1500: loss 2.038076
iteration 900 / 1500: loss 1.963754
iteration 1000 / 1500: loss 2.033816
iteration 1100 / 1500: loss 1.951089
iteration 1200 / 1500: loss 1.982663
iteration 1300 / 1500: loss 1.973714
iteration 1400 / 1500: loss 1.960978
iteration 0 / 1500: loss 20.178691
iteration 100 / 1500: loss 12.393123
iteration 200 / 1500: loss 8.669304
iteration 300 / 1500: loss 6.268383
iteration 400 / 1500: loss 4.771753
iteration 500 / 1500: loss 3.834443
iteration 600 / 1500: loss 3.081965
iteration 700 / 1500: loss 2.580636
iteration 800 / 1500: loss 2.300196
iteration 900 / 1500: loss 2.288218
iteration 1000 / 1500: loss 2.046215
iteration 1100 / 1500: loss 2.003026
iteration 1200 / 1500: loss 1.890517
iteration 1300 / 1500: loss 1.935527
iteration 1400 / 1500: loss 1.848145
iteration 0 / 1500: loss 779.600284
iteration 100 / 1500: loss 6.265374
iteration 200 / 1500: loss 5.897114
iteration 300 / 1500: loss 6.466074
iteration 400 / 1500: loss 8.701376
iteration 500 / 1500: loss 6.331864
iteration 600 / 1500: loss 7.310355
iteration 700 / 1500: loss 9.487596
iteration 800 / 1500: loss 8.777061
iteration 900 / 1500: loss 8.337180
iteration 1000 / 1500: loss 8.950924
iteration 1100 / 1500: loss 7.049873
iteration 1200 / 1500: loss 7.062818
iteration 1300 / 1500: loss 5.987070
iteration 1400 / 1500: loss 6.176888
```

```
iteration 0 / 1500: loss 1548.233324
iteration 100 / 1500: loss 19.109569
iteration 200 / 1500: loss 17.418868
iteration 300 / 1500: loss 14.281188
iteration 400 / 1500: loss 14.414467
iteration 500 / 1500: loss 19.237233
iteration 600 / 1500: loss 17.984188
iteration 700 / 1500: loss 16.298166
iteration 800 / 1500: loss 15.395685
iteration 900 / 1500: loss 17.522640
iteration 1000 / 1500: loss 13.729104
iteration 1100 / 1500: loss 14.814600
iteration 1200 / 1500: loss 15.727574
iteration 1300 / 1500: loss 16.120825
iteration 1400 / 1500: loss 15.266089
iteration 0 / 1500: loss 38.169843
iteration 100 / 1500: loss 3.521618
iteration 200 / 1500: loss 3.487077
iteration 300 / 1500: loss 2.271027
iteration 400 / 1500: loss 4.135099
iteration 500 / 1500: loss 4.256852
iteration 600 / 1500: loss 3.053705
iteration 700 / 1500: loss 3.431991
iteration 800 / 1500: loss 3.105041
iteration 900 / 1500: loss 3.354463
iteration 1000 / 1500: loss 4.535770
iteration 1100 / 1500: loss 5.070811
iteration 1200 / 1500: loss 4.424250
iteration 1300 / 1500: loss 2.529426
iteration 1400 / 1500: loss 3.991474
iteration 0 / 1500: loss 159.312591
iteration 100 / 1500: loss 3.961531
iteration 200 / 1500: loss 3.523365
iteration 300 / 1500: loss 5.557928
iteration 400 / 1500: loss 5.166877
iteration 500 / 1500: loss 3.671644
iteration 600 / 1500: loss 3.852356
iteration 700 / 1500: loss 4.094272
iteration 800 / 1500: loss 5.061596
iteration 900 / 1500: loss 5.873504
iteration 1000 / 1500: loss 4.421268
iteration 1100 / 1500: loss 3.851839
iteration 1200 / 1500: loss 3.563302
iteration 1300 / 1500: loss 3.227483
iteration 1400 / 1500: loss 4.808080
iteration 0 / 1500: loss 22.100505
iteration 100 / 1500: loss 5.716978
iteration 200 / 1500: loss 3.582975
iteration 300 / 1500: loss 3.065403
iteration 400 / 1500: loss 2.179274
iteration 500 / 1500: loss 2.557052
iteration 600 / 1500: loss 3.415070
iteration 700 / 1500: loss 2.596145
iteration 800 / 1500: loss 4.249764
iteration 900 / 1500: loss 3.015550
iteration 1000 / 1500: loss 4.648250
iteration 1100 / 1500: loss 2.963784
iteration 1200 / 1500: loss 2.842048
iteration 1300 / 1500: loss 2.894822
iteration 1400 / 1500: loss 2.790815
```

```
lr 1.000000e-07 reg 5.000000e+02 train accuracy: 0.259714 val accuracy: 0.290000
lr 1.000000e-07 reg 1.000000e+03 train accuracy: 0.266163 val accuracy: 0.264000
lr 1.000000e-07 reg 5.000000e+03 train accuracy: 0.332429 val accuracy: 0.340000
lr 1.000000e-07 reg 2.500000e+04 train accuracy: 0.330510 val accuracy: 0.341000
lr 1.000000e-07 reg 5.000000e+04 train accuracy: 0.306061 val accuracy: 0.324000
lr 5.000000e-07 reg 5.000000e+02 train accuracy: 0.365122 val accuracy: 0.362000
lr 5.000000e-07 reg 1.000000e+03 train accuracy: 0.390122 val accuracy: 0.399000
lr 5.000000e-07 reg 5.000000e+03 train accuracy: 0.374286 val accuracy: 0.375000
lr 5.000000e-07 reg 2.500000e+04 train accuracy: 0.318714 val accuracy: 0.332000
lr 5.000000e-07 reg 5.000000e+04 train accuracy: 0.304408 val accuracy: 0.315000
lr 2.000000e-06 reg 5.000000e+02 train accuracy: 0.397388 val accuracy: 0.391000
lr 2.000000e-06 reg 1.000000e+03 train accuracy: 0.397673 val accuracy: 0.394000
lr 2.000000e-06 reg 5.000000e+03 train accuracy: 0.353694 val accuracy: 0.360000
lr 2.000000e-06 reg 2.500000e+04 train accuracy: 0.285388 val accuracy: 0.304000
lr 2.000000e-06 reg 5.000000e+04 train accuracy: 0.272082 val accuracy: 0.280000
lr 1.000000e-05 reg 5.000000e+02 train accuracy: 0.289878 val accuracy: 0.312000
lr 1.000000e-05 reg 1.000000e+03 train accuracy: 0.252551 val accuracy: 0.251000
lr 1.000000e-05 reg 5.000000e+03 train accuracy: 0.216510 val accuracy: 0.248000
lr 1.000000e-05 reg 2.500000e+04 train accuracy: 0.097224 val accuracy: 0.093000
lr 1.000000e-05 reg 5.000000e+04 train accuracy: 0.099694 val accuracy: 0.097000
best validation accuracy achieved during cross-validation: 0.399000
```

In [ ]:
```python
# evaluate on test set
# Evaluate the best softmax on test set
y_test_pred = best_softmax.predict(X_test)
test_accuracy = np.mean(y_test == y_test_pred)
print('softmax on raw pixels final test set accuracy: %f' % (test_accuracy, ))
```

```
softmax on raw pixels final test set accuracy: 0.378000
```

Inline Question - *True or False*

It's possible to add a new data point to a training set that would leave the SVM loss unchanged, but this is not the case with the Softmax classifier loss.

Your answer: True.

Your explanation: In the case of an SVM loss, a new data point can have a margin that is already satisfied (i.e., the correct class score is sufficiently higher than the incorrect class scores by a margin), which would result in zero additional loss. In contrast, the Softmax classifier loss is based on probabilities, and every new data point contributes to the total probability distribution, so adding a new data point will always change the loss, even if it's a small change.

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

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

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

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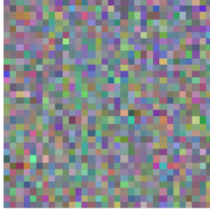
```
    plt.axis('off')
    plt.title(classes[i])
```

plane

car

bird

cat

deer

dog
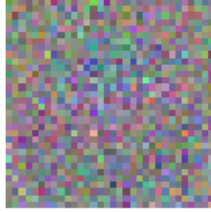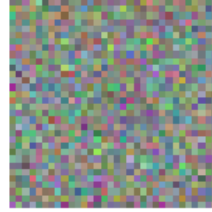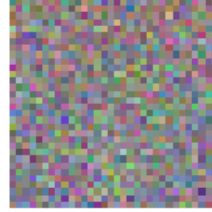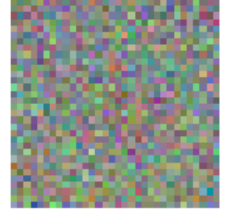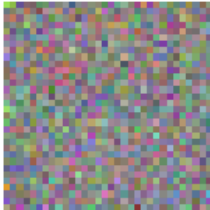
frog
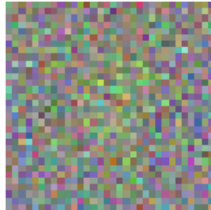
horse
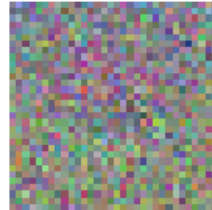
ship

truck

```
In [ ]:  # 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/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/$FOLDERNAME/cs6353/datasets/
         !bash get_datasets.sh
         %cd /content/drive/My\ Drive/$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/assignment2/cs6353/datasets
--2024-09-29 21:35:39--  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'

cifar-10-python.tar 100%[===================>] 162.60M  44.0MB/s    in 3.9s

2024-09-29 21:35:43 (41.7 MB/s) - 'cifar-10-python.tar.gz' saved [170498071/17049807
1]

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/assignment2
Requirement already satisfied: anyio==3.7.1 in /usr/local/lib/python3.10/dist-package
s (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//colab_
requirements.txt (line 1)) (3.7.1)
Collecting appnope==0.1.3 (from -r /content/drive/My Drive/CS6353/Assignments/assignm
ent2/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/assignment
2//colab_requirements.txt (line 3)) (23.1.0)
Requirement already satisfied: argon2-cffi-bindings==21.2.0 in /usr/local/lib/python
3.10/dist-packages (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/as
signment2//colab_requirements.txt (line 4)) (21.2.0)
Collecting arrow==1.2.3 (from -r /content/drive/My Drive/CS6353/Assignments/assignmen
t2/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/assig
nment2/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/assig
nment2/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/assignme
nt2/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/assignme
nt2/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-pack
ages (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//col
ab_requirements.txt (line 10)) (0.2.0)
Collecting beautifulsoup4==4.12.2 (from -r /content/drive/My Drive/CS6353/Assignment
s/assignment2/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/assignme
nt2/assignment2//colab_requirements.txt (line 12))
  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/ass
ignment2/assignment2//colab_requirements.txt (line 13))
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Collecting cffi==1.15.1 (from -r /content/drive/My Drive/CS6353/Assignments/assignmen
t2/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/Assignme
nts/assignment2/assignment2//colab_requirements.txt (line 15))
  Downloading charset_normalizer-3.2.0-cp310-cp310-manylinux_2_17_x86_64.manylinux201
4_x86_64.whl.metadata (31 kB)
Collecting comm==0.1.4 (from -r /content/drive/My Drive/CS6353/Assignments/assignment
2/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/assig
nment2/assignment2//colab_requirements.txt (line 17))
  Downloading contourpy-1.1.0-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.
whl.metadata (5.7 kB)
Collecting cycler==0.11.0 (from -r /content/drive/My Drive/CS6353/Assignments/assignm
ent2/assignment2//colab_requirements.txt (line 18))
  Downloading cycler-0.11.0-py3-none-any.whl.metadata (785 bytes)
Collecting debugpy==1.6.7.post1 (from -r /content/drive/My Drive/CS6353/Assignments/a
ssignment2/assignment2//colab_requirements.txt (line 19))
  Downloading debugpy-1.6.7.post1-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86
_64.whl.metadata (1.1 kB)
Requirement already satisfied: decorator<=5.0 in /usr/local/lib/python3.10/dist-packa
ges (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//cola
b_requirements.txt (line 20)) (4.4.2)
Requirement already satisfied: defusedxml==0.7.1 in /usr/local/lib/python3.10/dist-pa
ckages (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//c
olab_requirements.txt (line 21)) (0.7.1)
Collecting executing==1.2.0 (from -r /content/drive/My Drive/CS6353/Assignments/assig
nment2/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/Assignment
s/assignment2/assignment2//colab_requirements.txt (line 23))
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Collecting fonttools==4.42.1 (from -r /content/drive/My Drive/CS6353/Assignments/assi
gnment2/assignment2//colab_requirements.txt (line 24))
  Downloading fonttools-4.42.1-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_6
4.whl.metadata (150 kB)
  ──────────────────────────────────────── 151.0/151.0 kB 6.6 MB/s eta 0:00:00
Collecting fqdn==1.5.1 (from -r /content/drive/My Drive/CS6353/Assignments/assignment
2/assignment2//colab_requirements.txt (line 25))
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Collecting idna==3.4 (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/
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/assign
ment2/assignment2//colab_requirements.txt (line 27))
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Requirement already satisfied: ipykernel<=5.5.6 in /usr/local/lib/python3.10/dist-pac
kages (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//co
lab_requirements.txt (line 28)) (5.5.6)
Requirement already satisfied: ipython<=7.34.0 in /usr/local/lib/python3.10/dist-pack
ages (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//col
ab_requirements.txt (line 29)) (7.34.0)
Collecting isoduration==20.11.0 (from -r /content/drive/My Drive/CS6353/Assignments/a
ssignment2/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/assignmen
t2/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/assignme
nt2/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/assignme
nt2/assignment2//colab_requirements.txt (line 33))
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Collecting jsonpointer==2.4 (from -r /content/drive/My Drive/CS6353/Assignments/assig
nment2/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/ass
ignment2/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/CS635
3/Assignments/assignment2/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/assignment2//colab_requirements.txt (line 37))
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Collecting jupyter-lsp==2.2.0 (from -r /content/drive/My Drive/CS6353/Assignments/ass
ignment2/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-p
ackages (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//
colab_requirements.txt (line 39)) (6.1.12)
Collecting jupyter_core==5.3.1 (from -r /content/drive/My Drive/CS6353/Assignments/as
signment2/assignment2//colab_requirements.txt (line 40))
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Collecting jupyter_server==2.7.2 (from -r /content/drive/My Drive/CS6353/Assignments/
assignment2/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/As
signments/assignment2/assignment2//colab_requirements.txt (line 42))
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Collecting jupyterlab==4.0.5 (from -r /content/drive/My Drive/CS6353/Assignments/assi
gnment2/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/Assignm
ents/assignment2/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/Assignme
nts/assignment2/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/assi
gnment2/assignment2//colab_requirements.txt (line 46))
  Downloading kiwisolver-1.4.5-cp310-cp310-manylinux_2_12_x86_64.manylinux2010_x86_6
4.whl.metadata (6.4 kB)
Collecting MarkupSafe==2.1.3 (from -r /content/drive/My Drive/CS6353/Assignments/assi
gnment2/assignment2//colab_requirements.txt (line 47))
  Downloading MarkupSafe-2.1.3-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_6
4.whl.metadata (3.0 kB)
Collecting matplotlib==3.7.2 (from -r /content/drive/My Drive/CS6353/Assignments/assi
gnment2/assignment2//colab_requirements.txt (line 48))
  Downloading matplotlib-3.7.2-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_6
4.whl.metadata (5.6 kB)
Collecting matplotlib-inline==0.1.6 (from -r /content/drive/My Drive/CS6353/Assignmen
ts/assignment2/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/assignm
ent2/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/assign
ment2/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/assig
nment2/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/assign
ment2/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/as
signment2/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/a
ssignment2/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 Drive/CS6353/Assignments/assi
gnment2/assignment2//colab_requirements.txt (line 56))
  Downloading numpy-1.23.5-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.wh
l.metadata (2.3 kB)
Collecting overrides==7.4.0 (from -r /content/drive/My Drive/CS6353/Assignments/assig
nment2/assignment2//colab_requirements.txt (line 57))
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Collecting packaging==23.1 (from -r /content/drive/My Drive/CS6353/Assignments/assign
ment2/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/assignme
nt2/assignment2//colab_requirements.txt (line 59))
  Downloading pandas-1.5.3-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.wh
l.metadata (11 kB)
Collecting pandocfilters==1.5.0 (from -r /content/drive/My Drive/CS6353/Assignments/a
ssignment2/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/assignmen
t2/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/assignm
ent2/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-p
ackages (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//
colab_requirements.txt (line 63)) (0.7.5)
Collecting Pillow==10.0.0 (from -r /content/drive/My Drive/CS6353/Assignments/assignm
ent2/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/a
ssignment2/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/Assignme
nts/assignment2/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/Assignment
s/assignment2/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-packag
es (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//colab
_requirements.txt (line 68)) (5.9.5)
Requirement already satisfied: ptyprocess==0.7.0 in /usr/local/lib/python3.10/dist-pa

```
ckages (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//c
olab_requirements.txt (line 69)) (0.7.0)
Collecting pure-eval==0.2.2 (from -r /content/drive/My Drive/CS6353/Assignments/assig
nment2/assignment2//colab_requirements.txt (line 70))
  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/assign
ment2/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/assig
nment2/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/assig
nment2/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/di
st-packages (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignmen
t2//colab_requirements.txt (line 74)) (2.8.2)
Collecting python-json-logger==2.0.7 (from -r /content/drive/My Drive/CS6353/Assignme
nts/assignment2/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/assignmen
t2/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/assignme
nt2/assignment2//colab_requirements.txt (line 77))
  Downloading PyYAML-6.0.1-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.wh
l.metadata (2.1 kB)
Requirement already satisfied: pyzmq<25 in /usr/local/lib/python3.10/dist-packages (f
rom -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//colab_requ
irements.txt (line 78)) (24.0.1)
Collecting referencing==0.30.2 (from -r /content/drive/My Drive/CS6353/Assignments/as
signment2/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/assig
nment2/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/Assignmen
ts/assignment2/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/Assignmen
ts/assignment2/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/assignm
ent2/assignment2//colab_requirements.txt (line 83))
  Downloading rpds_py-0.9.2-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.wh
l.metadata (3.7 kB)
Collecting scipy==1.11.2 (from -r /content/drive/My Drive/CS6353/Assignments/assignme
nt2/assignment2//colab_requirements.txt (line 84))
  Downloading scipy-1.11.2-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.wh
l.metadata (59 kB)
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Collecting seaborn==0.12.2 (from -r /content/drive/My Drive/CS6353/Assignments/assign
ment2/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/assi
gnment2/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/assignment2//colab_re
quirements.txt (line 87)) (1.16.0)
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Collecting sniffio==1.3.0 (from -r /content/drive/My Drive/CS6353/Assignments/assignm
ent2/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/assig
nment2/assignment2//colab_requirements.txt (line 89))
  Downloading soupsieve-2.4.1-py3-none-any.whl.metadata (4.7 kB)
Collecting stack-data==0.6.2 (from -r /content/drive/My Drive/CS6353/Assignments/assi
gnment2/assignment2//colab_requirements.txt (line 90))
  Downloading stack_data-0.6.2-py3-none-any.whl.metadata (18 kB)
Collecting terminado==0.17.1 (from -r /content/drive/My Drive/CS6353/Assignments/assi
gnment2/assignment2//colab_requirements.txt (line 91))
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Collecting tinycss2==1.2.1 (from -r /content/drive/My Drive/CS6353/Assignments/assign
ment2/assignment2//colab_requirements.txt (line 92))
  Downloading tinycss2-1.2.1-py3-none-any.whl.metadata (3.0 kB)
Collecting tornado<=6.3.2 (from -r /content/drive/My Drive/CS6353/Assignments/assignm
ent2/assignment2//colab_requirements.txt (line 93))
  Downloading tornado-6.3.2-cp38-abi3-manylinux_2_5_x86_64.manylinux1_x86_64.manylinu
x_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/assig
nment2/assignment2//colab_requirements.txt (line 94))
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Collecting tzdata==2023.3 (from -r /content/drive/My Drive/CS6353/Assignments/assignm
ent2/assignment2//colab_requirements.txt (line 95))
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signment2/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/assignm
ent2/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/assignm
ent2/assignment2//colab_requirements.txt (line 98))
  Downloading wcwidth-0.2.6-py2.py3-none-any.whl.metadata (11 kB)
Collecting webcolors==1.13 (from -r /content/drive/My Drive/CS6353/Assignments/assign
ment2/assignment2//colab_requirements.txt (line 99))
  Downloading webcolors-1.13-py3-none-any.whl.metadata (2.6 kB)
Requirement already satisfied: webencodings==0.5.1 in /usr/local/lib/python3.10/dist-
packages (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment
2//colab_requirements.txt (line 100)) (0.5.1)
Collecting websocket-client==1.6.2 (from -r /content/drive/My Drive/CS6353/Assignment
s/assignment2/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-packa
ges (from anyio==3.7.1->-r /content/drive/My Drive/CS6353/Assignments/assignment2/ass
ignment2//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/a
ssignment2/assignment2//colab_requirements.txt (line 7)) (4.12.2)
Collecting jupyter_client<8.0 (from -r /content/drive/My Drive/CS6353/Assignments/ass
ignment2/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/assignme
nt2//colab_requirements.txt (line 43)) (2.0.1)
Requirement already satisfied: ipython-genutils in /usr/local/lib/python3.10/dist-pac
kages (from ipykernel<=5.5.6->-r /content/drive/My Drive/CS6353/Assignments/assignmen
t2/assignment2//colab_requirements.txt (line 28)) (0.2.0)
Requirement already satisfied: setuptools>=18.5 in /usr/local/lib/python3.10/dist-pac
kages (from ipython<=7.34.0->-r /content/drive/My Drive/CS6353/Assignments/assignment

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2/assignment2//colab_requirements.txt (line 29)) (71.0.4)
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/a
ssignment2//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)
                                    ──────────────────────── 66.4/66.4 kB 3.4 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)
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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)
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Downloading bleach-6.0.0-py3-none-any.whl (162 kB)
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Downloading certifi-2023.7.22-py3-none-any.whl (158 kB)
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41 kB)
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x86_64.whl (201 kB)
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Downloading comm-0.1.4-py3-none-any.whl (6.6 kB)
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Downloading debugpy-1.6.7.post1-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_6
4.whl (3.0 MB)
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Downloading fastjsonschema-2.18.0-py3-none-any.whl (23 kB)
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Downloading json5-0.9.14-py2.py3-none-any.whl (19 kB)
Downloading jsonpointer-2.4-py2.py3-none-any.whl (7.8 kB)
Downloading jsonschema-4.19.0-py3-none-any.whl (83 kB)
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Downloading jsonschema_specifications-2023.7.1-py3-none-any.whl (17 kB)
Downloading jupyter_events-0.7.0-py3-none-any.whl (18 kB)
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Downloading jupyterlab_pygments-0.2.2-py2.py3-none-any.whl (21 kB)
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hl (25 kB)
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hl (11.6 MB)
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Downloading matplotlib_inline-0.1.6-py3-none-any.whl (9.4 kB)
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Downloading notebook_shim-0.2.3-py3-none-any.whl (13 kB)
Downloading overrides-7.4.0-py3-none-any.whl (17 kB)
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Downloading pandocfilters-1.5.0-py2.py3-none-any.whl (8.7 kB)
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Downloading platformdirs-3.10.0-py3-none-any.whl (17 kB)
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Downloading terminado-0.17.1-py3-none-any.whl (17 kB)
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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)
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Installing collected packages: wcwidth, pytz, pure-eval, json5, fastjsonschema, execu
ting, appnope, websocket-client, webcolors, urllib3, uri-template, tzdata, traitlets,
tornado, tinycss2, soupsieve, sniffio, Send2Trash, rpds-py, rfc3986-validator, rfc333
9-validator, PyYAML, python-json-logger, pyparsing, Pygments, pycparser, prompt-toolk
it, prometheus-client, platformdirs, Pillow, pexpect, parso, pandocfilters, packagin
g, overrides, numpy, nest-asyncio, mistune, MarkupSafe, kiwisolver, jupyterlab-pygmen
ts, jsonpointer, idna, fqdn, fonttools, debugpy, cycler, charset-normalizer, certifi,
bleach, Babel, attrs, async-lru, asttokens, terminado, stack-data, scipy, requests, r
eferencing, pandas, matplotlib-inline, jupyter_core, Jinja2, jedi, imageio, contourp
y, comm, cffi, beautifulsoup4, arrow, matplotlib, jupyter_server_terminals, jupyter_c
lient, jsonschema-specifications, isoduration, seaborn, jsonschema, nbformat, nbclien
t, jupyter-events, nbconvert, jupyter_server, notebook_shim, jupyterlab_server, jupyt
er-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 2.20.0
    Uninstalling fastjsonschema-2.20.0:
      Successfully uninstalled fastjsonschema-2.20.0
  Attempting uninstall: websocket-client
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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 24.8.0
Uninstalling webcolors-24.8.0:
  Successfully uninstalled webcolors-24.8.0
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 2024.1
Uninstalling tzdata-2024.1:
  Successfully uninstalled tzdata-2024.1
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
Uninstalling tornado-6.3.3:
  Successfully uninstalled tornado-6.3.3
Attempting uninstall: tinycss2
Found existing installation: tinycss2 1.3.0
Uninstalling tinycss2-1.3.0:
  Successfully uninstalled tinycss2-1.3.0
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 0.20.0
Uninstalling rpds-py-0.20.0:
  Successfully uninstalled rpds-py-0.20.0
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 3.1.4
Uninstalling pyparsing-3.1.4:
  Successfully uninstalled pyparsing-3.1.4
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 3.0.47
       Uninstalling prompt_toolkit-3.0.47:
         Successfully uninstalled prompt_toolkit-3.0.47
     Attempting uninstall: prometheus-client
       Found existing installation: prometheus_client 0.21.0
       Uninstalling prometheus_client-0.21.0:
         Successfully uninstalled prometheus_client-0.21.0
     Attempting uninstall: platformdirs
       Found existing installation: platformdirs 4.3.6
       Uninstalling platformdirs-4.3.6:
         Successfully uninstalled platformdirs-4.3.6
     Attempting uninstall: Pillow
       Found existing installation: pillow 10.4.0
       Uninstalling pillow-10.4.0:
         Successfully uninstalled pillow-10.4.0
     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 24.1
       Uninstalling packaging-24.1:
         Successfully uninstalled packaging-24.1
     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 0.8.4
       Uninstalling mistune-0.8.4:
         Successfully uninstalled mistune-0.8.4
     Attempting uninstall: MarkupSafe
       Found existing installation: MarkupSafe 2.1.5
       Uninstalling MarkupSafe-2.1.5:
         Successfully uninstalled MarkupSafe-2.1.5
     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: idna
       Found existing installation: idna 3.10
       Uninstalling idna-3.10:
         Successfully uninstalled idna-3.10
     Attempting uninstall: fonttools
```

```
        Found existing installation: fonttools 4.53.1
        Uninstalling fonttools-4.53.1:
          Successfully uninstalled fonttools-4.53.1
      Attempting uninstall: debugpy
        Found existing installation: debugpy 1.6.6
        Uninstalling debugpy-1.6.6:
          Successfully uninstalled debugpy-1.6.6
      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 3.3.2
        Uninstalling charset-normalizer-3.3.2:
          Successfully uninstalled charset-normalizer-3.3.2
      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 6.1.0
        Uninstalling bleach-6.1.0:
          Successfully uninstalled bleach-6.1.0
      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 2.1.4
        Uninstalling pandas-2.1.4:
          Successfully uninstalled pandas-2.1.4
      Attempting uninstall: matplotlib-inline
        Found existing installation: matplotlib-inline 0.1.7
        Uninstalling matplotlib-inline-0.1.7:
          Successfully uninstalled matplotlib-inline-0.1.7
      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
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                Uninstalling imageio-2.35.1:
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            Attempting uninstall: contourpy
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                    Successfully uninstalled contourpy-1.3.0
            Attempting uninstall: cffi
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                    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
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                Uninstalling matplotlib-3.7.1:
                    Successfully uninstalled matplotlib-3.7.1
            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 2023.12.1
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            Attempting uninstall: seaborn
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                    Successfully uninstalled seaborn-0.13.1
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                    Successfully uninstalled jsonschema-4.23.0
            Attempting uninstall: nbformat
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                Uninstalling nbformat-5.10.4:
                    Successfully uninstalled nbformat-5.10.4
            Attempting uninstall: nbclient
                Found existing installation: nbclient 0.10.0
                Uninstalling nbclient-0.10.0:
                    Successfully uninstalled nbclient-0.10.0
            Attempting uninstall: nbconvert
                Found existing installation: nbconvert 6.5.4
                Uninstalling nbconvert-6.5.4:
                    Successfully uninstalled nbconvert-6.5.4
            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 package
```

```
s that are installed. This behaviour is the source of the following dependency confli
cts.
albucore 0.0.16 requires numpy>=1.24, but you have numpy 1.23.5 which is incompatibl
e.
albumentations 1.4.15 requires numpy>=1.24.4, but you have numpy 1.23.5 which is inco
mpatible.
bigframes 1.18.0 requires numpy>=1.24.0, but you have numpy 1.23.5 which is incompati
ble.
bokeh 3.4.3 requires contourpy>=1.2, but you have contourpy 1.1.0 which is incompatib
le.
chex 0.1.86 requires numpy>=1.24.1, but you have numpy 1.23.5 which is incompatible.
cudf-cu12 24.4.1 requires pandas<2.2.2dev0,>=2.0, but you have pandas 1.5.3 which is
incompatible.
google-colab 1.0.0 requires pandas==2.1.4, but you have pandas 1.5.3 which is incompa
tible.
google-colab 1.0.0 requires requests==2.32.3, but you have requests 2.31.0 which is i
ncompatible.
google-colab 1.0.0 requires tornado==6.3.3, but you have tornado 6.3.2 which is incom
patible.
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.
mizani 0.11.4 requires pandas>=2.1.0, but you have pandas 1.5.3 which is incompatibl
e.
pandas-stubs 2.1.4.231227 requires numpy>=1.26.0; python_version < "3.13", but you ha
ve numpy 1.23.5 which is incompatible.
plotnine 0.13.6 requires pandas<3.0.0,>=2.1.0, but you have pandas 1.5.3 which is inc
ompatible.
scikit-image 0.24.0 requires imageio>=2.33, but you have imageio 2.31.1 which is inco
mpatible.
xarray 2024.9.0 requires numpy>=1.24, but you have numpy 1.23.5 which is incompatibl
e.
xarray 2024.9.0 requires pandas>=2.1, but you have pandas 1.5.3 which is incompatibl
e.
Successfully installed Babel-2.12.1 Jinja2-3.1.2 MarkupSafe-2.1.3 Pillow-10.0.0 PyYAM
L-6.0.1 Pygments-2.16.1 Send2Trash-1.8.2 appnope-0.1.3 arrow-1.2.3 asttokens-2.2.1 as
ync-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 im
ageio-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 jupy
ter_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 platfor
mdirs-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 request
s-2.31.0 rfc3339-validator-0.1.4 rfc3986-validator-0.1.1 rpds-py-0.9.2 scipy-1.11.2 s
eaborn-0.12.2 sniffio-1.3.0 soupsieve-2.4.1 stack-data-0.6.2 terminado-0.17.1 tinycss
2-1.2.1 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
```

Implementing a Neural Network

In this exercise we will develop a neural network with fully-connected layers to perform classification, and test it out on the CIFAR-10 dataset.

```
In [ ]:  # A bit of setup

         from __future__ import print_function
         import numpy as np
         import matplotlib.pyplot as plt

         from cs6353.classifiers.neural_net import TwoLayerNet


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

         def rel_error(x, y):
             """ returns relative error """
             return np.max(np.abs(x - y) / (np.maximum(1e-8, np.abs(x) + np.abs(y))))
```

We will use the class `TwoLayerNet` in the file `cs6353/classifiers/neural_net.py` to represent instances of our network. The network parameters are stored in the instance variable `self.params` where keys are string parameter names and values are numpy arrays. Below, we initialize toy data and a toy model that we will use to develop your implementation.

```
In [ ]:  # Create a small net and some toy data to check your implementations.
         # Note that we set the random seed for repeatable experiments.

         input_size = 4
         hidden_size = 10
         num_classes = 3
         num_inputs = 5

         def init_toy_model():
             np.random.seed(0)
             return TwoLayerNet(input_size, hidden_size, num_classes, std=1e-1)

         def init_toy_data():
             np.random.seed(1)
             X = 10 * np.random.randn(num_inputs, input_size)
             y = np.array([0, 1, 2, 2, 1])
             return X, y

         net = init_toy_model()
         X, y = init_toy_data()
```

Forward pass: compute scores

Open the file `cs6353/classifiers/neural_net.py` and look at the method `TwoLayerNet.loss`. This function is very similar to the loss functions you have written for the

SVM and Softmax exercises: It takes the data and weights and computes the class scores, the loss, and the gradients on the parameters.

Implement the first part of the forward pass which uses the weights and biases to compute the scores for all inputs.

```
In [ ]:  scores = net.loss(X)
         print('Your scores:')
         print(scores)
         print()
         print('correct scores:')
         correct_scores = np.asarray([
            [-0.81233741, -1.27654624, -0.70335995],
            [-0.17129677, -1.18803311, -0.47310444],
            [-0.51590475, -1.01354314, -0.8504215 ],
            [-0.15419291, -0.48629638, -0.52901952],
            [-0.00618733, -0.12435261, -0.15226949]])
         print(correct_scores)
         print()

         # The difference should be very small. We get < 1e-7
         print('Difference between your scores and correct scores:')
         print(np.sum(np.abs(scores - correct_scores)))
```

```
Your scores:
[[-0.81233741 -1.27654624 -0.70335995]
 [-0.17129677 -1.18803311 -0.47310444]
 [-0.51590475 -1.01354314 -0.8504215 ]
 [-0.15419291 -0.48629638 -0.52901952]
 [-0.00618733 -0.12435261 -0.15226949]]

correct scores:
[[-0.81233741 -1.27654624 -0.70335995]
 [-0.17129677 -1.18803311 -0.47310444]
 [-0.51590475 -1.01354314 -0.8504215 ]
 [-0.15419291 -0.48629638 -0.52901952]
 [-0.00618733 -0.12435261 -0.15226949]]

Difference between your scores and correct scores:
3.6802720745909845e-08
```

Forward pass: compute loss

In the same function, implement the second part that computes the data and regularization loss.

```
In [ ]:  loss, _ = net.loss(X, y, reg=0.05)
         correct_loss = 1.30378789133

         # should be very small, we get < 1e-12
         print('Difference between your loss and correct loss:')
         print(np.sum(np.abs(loss - correct_loss)))
```

```
Difference between your loss and correct loss:
1.7985612998927536e-13
```

Backward pass

Implement the rest of the function. This will compute the gradient of the loss with respect to the variables `W1`, `b1`, `W2`, and `b2`. Now that you (hopefully!) have a correctly implemented forward pass, you can debug your backward pass using a numeric gradient check:

```
from cs6353.gradient_check import eval_numerical_gradient

# Use numeric gradient checking to check your implementation of the backward pass.
# If your implementation is correct, the difference between the numeric and
# analytic gradients should be less than 1e-8 for each of W1, W2, b1, and b2.

loss, grads = net.loss(X, y, reg=0.05)

# these should all be less than 1e-8 or so
for param_name in grads:
    f = lambda W: net.loss(X, y, reg=0.05)[0]
    param_grad_num = eval_numerical_gradient(f, net.params[param_name], verbose=False)
    print('%s max relative error: %e' % (param_name, rel_error(param_grad_num, grads[param_name])))
```

```
W2 max relative error: 3.440708e-09
b2 max relative error: 4.447625e-11
W1 max relative error: 3.561318e-09
b1 max relative error: 2.738421e-09
```

Train the network

To train the network we will use stochastic gradient descent (SGD), similar to the SVM and Softmax classifiers. Look at the function `TwoLayerNet.train` and fill in the missing sections to implement the training procedure. This should be very similar to the training procedure you used for the SVM and Softmax classifiers. You will also have to implement `TwoLayerNet.predict`, as the training process periodically performs prediction to keep track of accuracy over time while the network trains.

Once you have implemented the method, run the code below to train a two-layer network on toy data. You should achieve a training loss less than 0.2.

```
net = init_toy_model()
stats = net.train(X, y, X, y,
            learning_rate=1e-1, reg=5e-6,
            num_iters=100, verbose=False)

print('Final training loss: ', stats['loss_history'][-1])

# plot the loss history
plt.plot(stats['loss_history'])
plt.xlabel('iteration')
plt.ylabel('training loss')
plt.title('Training Loss history')
plt.show()
```

Final training loss: 0.017149607938732093
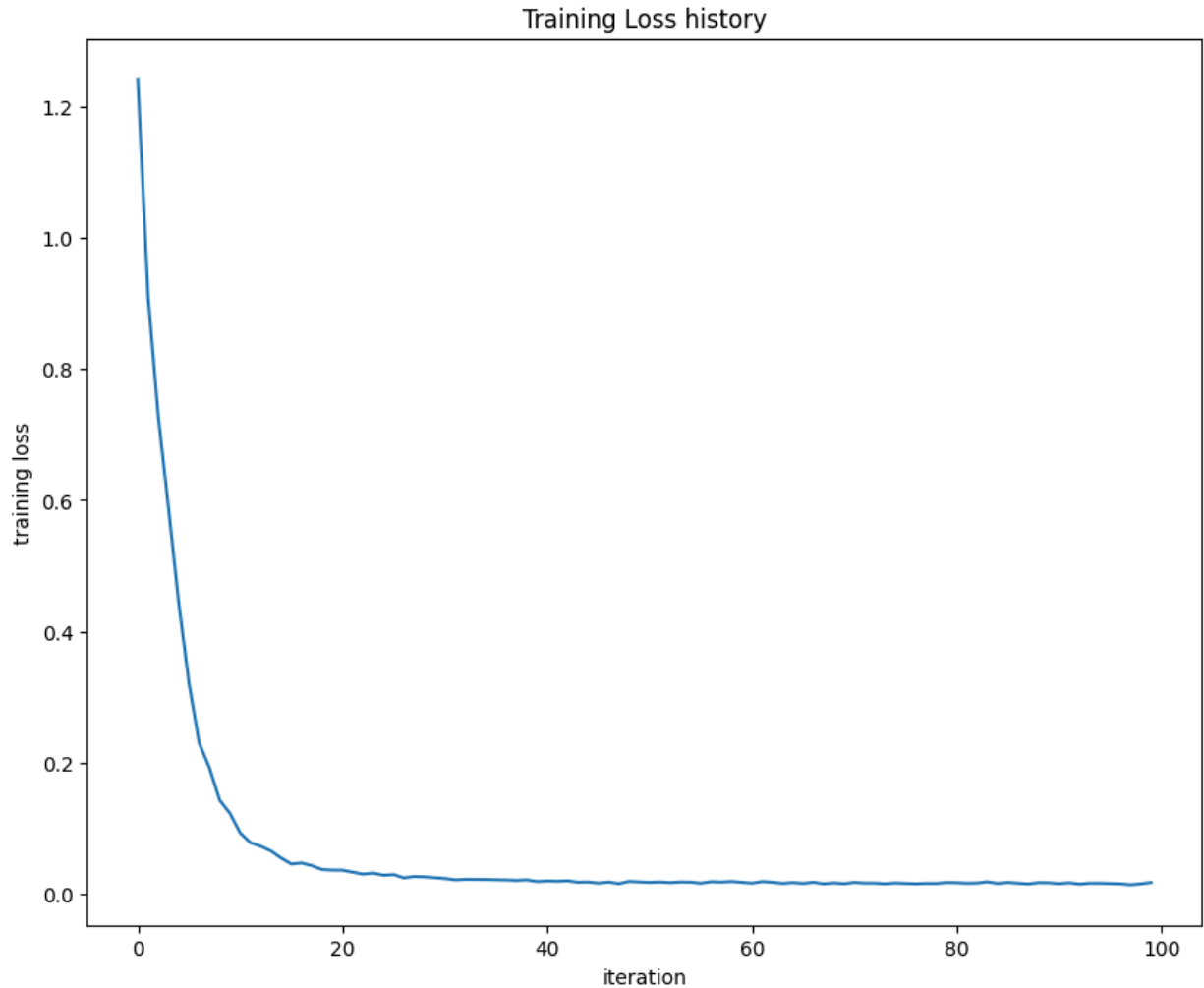
Load the data

Now that you have implemented a two-layer network that passes gradient checks and works on toy data, it's time to load up our favorite CIFAR-10 data so we can use it to train a classifier on a real dataset.

```
In [ ]:  from cs6353.data_utils import load_CIFAR10

         def get_CIFAR10_data(num_training=49000, num_validation=1000, num_test=1000):
             """
             Load the CIFAR-10 dataset from disk and perform preprocessing to prepare
             it for the two-layer neural net classifier. These are the same steps as
             we used for the SVM, but condensed to a single function.
             """
             # Load the raw CIFAR-10 data
             cifar10_dir = 'cs6353/datasets/cifar-10-batches-py'

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

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

```python
        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]

        # Normalize the data: subtract the mean image
        mean_image = np.mean(X_train, axis=0)
        X_train -= mean_image
        X_val -= mean_image
        X_test -= mean_image

        # Reshape data to rows
        X_train = X_train.reshape(num_training, -1)
        X_val = X_val.reshape(num_validation, -1)
        X_test = X_test.reshape(num_test, -1)

        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
try:
    del X_train, y_train
    del X_test, y_test
    print('Clear previously loaded data.')
except:
    pass

# Invoke the above function to get our data.
X_train, y_train, X_val, y_val, X_test, y_test = get_CIFAR10_data()
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)
```

```
Train data shape:  (49000, 3072)
Train labels shape:  (49000,)
Validation data shape:  (1000, 3072)
Validation labels shape:  (1000,)
Test data shape:  (1000, 3072)
Test labels shape:  (1000,)
```

Train a network

To train our network we will use SGD. In addition, we will adjust the learning rate with an exponential learning rate schedule as optimization proceeds; after each epoch, we will reduce the learning rate by multiplying it by a decay rate.

```python
In [ ]:  input_size = 32 * 32 * 3
         hidden_size = 50
         num_classes = 10
         net = TwoLayerNet(input_size, hidden_size, num_classes)

         # Train the network
```

```
stats = net.train(X_train, y_train, X_val, y_val,
            num_iters=1000, batch_size=200,
            learning_rate=1e-4, learning_rate_decay=0.95,
            reg=0.25, verbose=True)

# Predict on the validation set
val_acc = (net.predict(X_val) == y_val).mean()
print('Validation accuracy: ', val_acc)
```

```
iteration 0 / 1000: loss 2.302954
iteration 100 / 1000: loss 2.302550
iteration 200 / 1000: loss 2.297648
iteration 300 / 1000: loss 2.259602
iteration 400 / 1000: loss 2.204170
iteration 500 / 1000: loss 2.118565
iteration 600 / 1000: loss 2.051535
iteration 700 / 1000: loss 1.988466
iteration 800 / 1000: loss 2.006591
iteration 900 / 1000: loss 1.951473
Validation accuracy:  0.287
```

Debug the training

With the default parameters we provided above, you should get a validation accuracy of about 0.29 on the validation set. This isn't very good.

One strategy for getting insight into what's wrong is to plot the loss function and the accuracies on the training and validation sets during optimization.

Another strategy is to visualize the weights that were learned in the first layer of the network. In most neural networks trained on visual data, the first layer weights typically show some visible structure when visualized.

```
In [ ]:  # Plot the loss function and train / validation accuracies
         plt.subplot(2, 1, 1)
         plt.plot(stats['loss_history'])
         plt.title('Loss history')
         plt.xlabel('Iteration')
         plt.ylabel('Loss')

         plt.subplot(2, 1, 2)
         plt.plot(stats['train_acc_history'], label='train')
         plt.plot(stats['val_acc_history'], label='val')
         plt.title('Classification accuracy history')
         plt.xlabel('Epoch')
         plt.ylabel('Clasification accuracy')
         plt.legend()
         plt.show()
```

Loss history

Classification accuracy history
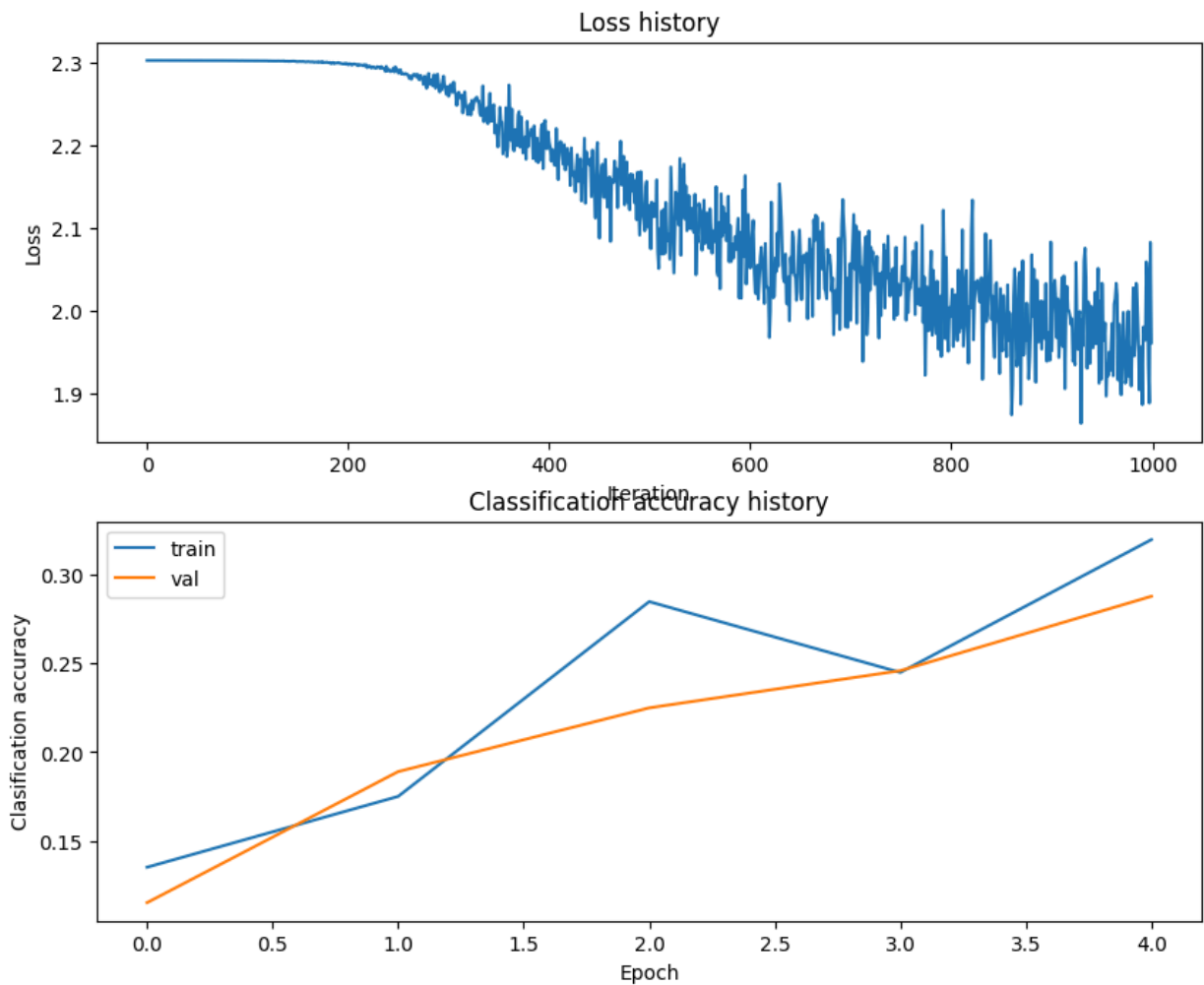
In [ ]:
```python
from cs6353.vis_utils import visualize_grid

# Visualize the weights of the network

def show_net_weights(net):
    W1 = net.params['W1']
    W1 = W1.reshape(32, 32, 3, -1).transpose(3, 0, 1, 2)
    plt.imshow(visualize_grid(W1, padding=3).astype('uint8'))
    plt.gca().axis('off')
    plt.show()

show_net_weights(net)
```
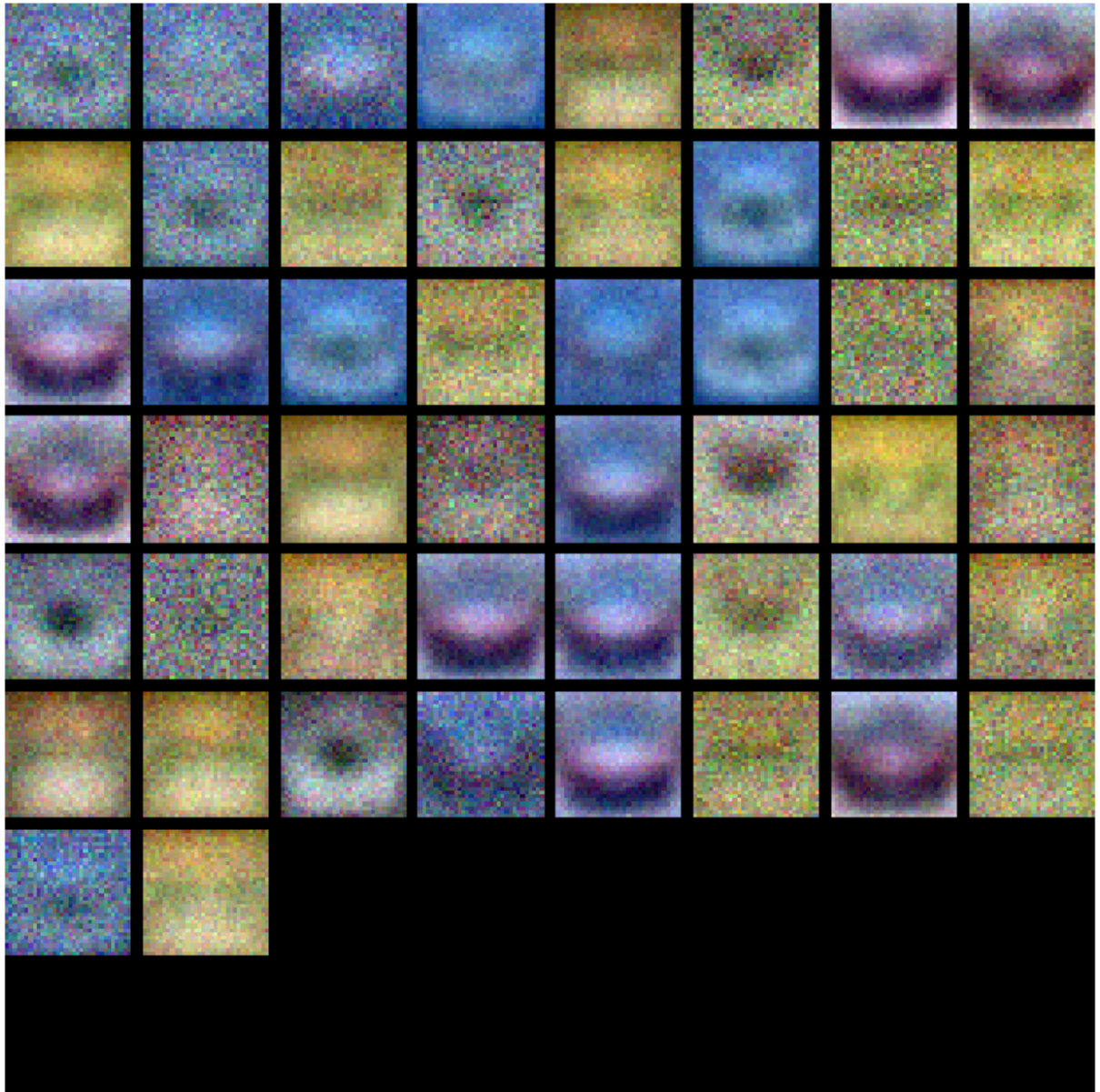
Tune your hyperparameters

What's wrong?. Looking at the visualizations above, we see that the loss is decreasing more or less linearly, which seems to suggest that the learning rate may be too low. Moreover, there is no gap between the training and validation accuracy, suggesting that the model we used has low capacity, and that we should increase its size. On the other hand, with a very large model we would expect to see more overfitting, which would manifest itself as a very large gap between the training and validation accuracy.

Tuning. Tuning the hyperparameters and developing intuition for how they affect the final performance is a large part of using Neural Networks, so we want you to get a lot of practice. Below, you should experiment with different values of the various hyperparameters, including hidden layer size, learning rate, number of training epochs, and regularization strength. You

might also consider tuning the learning rate decay, but you should be able to get good performance using the default value.

Approximate results. You should be aim to achieve a classification accuracy of greater than 48% on the validation set. Our best network gets over 52% on the validation set.

Experiment: You goal in this exercise is to get as good of a result on CIFAR-10 as you can, with a fully-connected Neural Network. Feel free implement your own techniques (e.g. PCA to reduce dimensionality, or adding dropout, or adding features to the solver, etc.).

```python
In [ ]:   best_net = None # store the best model into this

          #############################################################################
          # TODO: Tune hyperparameters using the validation set. Store your best trained  #
          # model in best_net.                                                        #
          #                                                                           #
          # To help debug your network, it may help to use visualizations similar to the  #
          # ones we used above; these visualizations will have significant qualitative    #
          # differences from the ones we saw above for the poorly tuned network.      #
          #                                                                           #
          # Tweaking hyperparameters by hand can be fun, but you might find it useful to  #
          # write code to sweep through possible combinations of hyperparameters      #
          # automatically like we did on the previous exercises.                      #
          #############################################################################
          learning_rates = [1e-3, 2e-3]
          regularization_strengths = [0.01, 0.05, 0.1, 0.2]
          hidden_layer_sizes = [10, 50, 75, 100, 175]
          num_of_epochs = [1500]
          results = {}
          best_val = -1
          X_train, y_train, X_val, y_val, X_test, y_test = get_CIFAR10_data()


          for lr in learning_rates:
              for reg in regularization_strengths:
                  for hls in hidden_layer_sizes:
                      for epochs in num_of_epochs:

                          input_size = 32 * 32 * 3
                          num_classes = 10
                          net = TwoLayerNet(input_size, hls, num_classes)

                          stats = net.train(X_train, y_train, X_val, y_val,
                              num_iters=epochs, batch_size=200,
                              learning_rate=lr, learning_rate_decay=0.95,
                              reg=reg, verbose=True)

                          y_train_pred = net.predict(X_train)
                          y_val_pred = net.predict(X_val)

                          train_acc = np.mean(y_train_pred == y_train)
                          val_acc = np.mean(y_val_pred == y_val)


                          results[(lr, reg, hls, epochs)] = (train_acc, val_acc)
                          print(lr, reg, hls, epochs, train_acc, val_acc)
```

```python
            if val_acc > best_val:
                best_val = val_acc
                best_net = net

for lr, reg, hls, epochs in sorted(results):
    train_accuracy, val_accuracy = results[(lr, reg, hls, epochs)]
    print('lr %e reg %e hidden_size %e num_training_epochs %e train accuracy: %f val a
            lr, reg, hls, epochs, train_accuracy, val_accuracy))

print('best validation accuracy achieved during cross-validation: %f' % best_val)
###############################################################################
#                              END OF YOUR CODE                               #
###############################################################################
```

```
iteration 0 / 1500: loss 2.302581
iteration 100 / 1500: loss 1.974147
iteration 200 / 1500: loss 1.825872
iteration 300 / 1500: loss 1.809073
iteration 400 / 1500: loss 1.829164
iteration 500 / 1500: loss 1.608163
iteration 600 / 1500: loss 1.788503
iteration 700 / 1500: loss 1.677658
iteration 800 / 1500: loss 1.636122
iteration 900 / 1500: loss 1.646538
iteration 1000 / 1500: loss 1.730433
iteration 1100 / 1500: loss 1.552284
iteration 1200 / 1500: loss 1.610167
iteration 1300 / 1500: loss 1.747374
iteration 1400 / 1500: loss 1.615684
0.001 0.01 10 1500 0.41981632653061224 0.405
iteration 0 / 1500: loss 2.302573
iteration 100 / 1500: loss 1.939704
iteration 200 / 1500: loss 1.653989
iteration 300 / 1500: loss 1.675380
iteration 400 / 1500: loss 1.629272
iteration 500 / 1500: loss 1.652488
iteration 600 / 1500: loss 1.521493
iteration 700 / 1500: loss 1.569525
iteration 800 / 1500: loss 1.408117
iteration 900 / 1500: loss 1.503961
iteration 1000 / 1500: loss 1.545182
iteration 1100 / 1500: loss 1.522084
iteration 1200 / 1500: loss 1.342073
iteration 1300 / 1500: loss 1.392764
iteration 1400 / 1500: loss 1.411536
0.001 0.01 50 1500 0.5157551020408163 0.478
iteration 0 / 1500: loss 2.302603
iteration 100 / 1500: loss 1.847776
iteration 200 / 1500: loss 1.834582
iteration 300 / 1500: loss 1.694456
iteration 400 / 1500: loss 1.613538
iteration 500 / 1500: loss 1.573353
iteration 600 / 1500: loss 1.646094
iteration 700 / 1500: loss 1.393890
iteration 800 / 1500: loss 1.561888
iteration 900 / 1500: loss 1.411730
iteration 1000 / 1500: loss 1.368661
iteration 1100 / 1500: loss 1.373301
iteration 1200 / 1500: loss 1.417317
iteration 1300 / 1500: loss 1.434986
iteration 1400 / 1500: loss 1.358610
0.001 0.01 75 1500 0.5349387755102041 0.494
iteration 0 / 1500: loss 2.302631
iteration 100 / 1500: loss 1.891271
iteration 200 / 1500: loss 1.841134
iteration 300 / 1500: loss 1.608803
iteration 400 / 1500: loss 1.745047
iteration 500 / 1500: loss 1.546296
iteration 600 / 1500: loss 1.540214
iteration 700 / 1500: loss 1.415954
iteration 800 / 1500: loss 1.533922
iteration 900 / 1500: loss 1.434874
iteration 1000 / 1500: loss 1.495634
iteration 1100 / 1500: loss 1.457333
```

```
iteration 1200 / 1500: loss 1.403894
iteration 1300 / 1500: loss 1.417297
iteration 1400 / 1500: loss 1.295456
0.001 0.01 100 1500 0.5325918367346939 0.488
iteration 0 / 1500: loss 2.302667
iteration 100 / 1500: loss 1.848674
iteration 200 / 1500: loss 1.697099
iteration 300 / 1500: loss 1.725101
iteration 400 / 1500: loss 1.560017
iteration 500 / 1500: loss 1.597732
iteration 600 / 1500: loss 1.532332
iteration 700 / 1500: loss 1.437468
iteration 800 / 1500: loss 1.467007
iteration 900 / 1500: loss 1.432513
iteration 1000 / 1500: loss 1.424042
iteration 1100 / 1500: loss 1.475901
iteration 1200 / 1500: loss 1.449034
iteration 1300 / 1500: loss 1.376109
iteration 1400 / 1500: loss 1.368243
0.001 0.01 175 1500 0.5448571428571428 0.479
iteration 0 / 1500: loss 2.302615
iteration 100 / 1500: loss 1.984518
iteration 200 / 1500: loss 1.871146
iteration 300 / 1500: loss 1.806074
iteration 400 / 1500: loss 1.644300
iteration 500 / 1500: loss 1.753788
iteration 600 / 1500: loss 1.669483
iteration 700 / 1500: loss 1.774881
iteration 800 / 1500: loss 1.796813
iteration 900 / 1500: loss 1.669230
iteration 1000 / 1500: loss 1.582772
iteration 1100 / 1500: loss 1.666023
iteration 1200 / 1500: loss 1.579431
iteration 1300 / 1500: loss 1.636563
iteration 1400 / 1500: loss 1.531957
0.001 0.05 10 1500 0.4174897959183673 0.393
iteration 0 / 1500: loss 2.302648
iteration 100 / 1500: loss 1.899407
iteration 200 / 1500: loss 1.826842
iteration 300 / 1500: loss 1.830116
iteration 400 / 1500: loss 1.626270
iteration 500 / 1500: loss 1.571816
iteration 600 / 1500: loss 1.623560
iteration 700 / 1500: loss 1.495094
iteration 800 / 1500: loss 1.465571
iteration 900 / 1500: loss 1.386988
iteration 1000 / 1500: loss 1.577928
iteration 1100 / 1500: loss 1.391478
iteration 1200 / 1500: loss 1.578307
iteration 1300 / 1500: loss 1.392800
iteration 1400 / 1500: loss 1.370366
0.001 0.05 50 1500 0.5179795918367347 0.495
iteration 0 / 1500: loss 2.302732
iteration 100 / 1500: loss 1.965302
iteration 200 / 1500: loss 1.866580
iteration 300 / 1500: loss 1.760200
iteration 400 / 1500: loss 1.597303
iteration 500 / 1500: loss 1.611230
iteration 600 / 1500: loss 1.594060
iteration 700 / 1500: loss 1.482644
```

```
                    iteration 800 / 1500: loss 1.459311
                    iteration 900 / 1500: loss 1.393259
                    iteration 1000 / 1500: loss 1.425219
                    iteration 1100 / 1500: loss 1.538297
                    iteration 1200 / 1500: loss 1.411221
                    iteration 1300 / 1500: loss 1.457041
                    iteration 1400 / 1500: loss 1.308681
                    0.001 0.05 75 1500 0.5263265306122449 0.478
                    iteration 0 / 1500: loss 2.302727
                    iteration 100 / 1500: loss 1.896443
                    iteration 200 / 1500: loss 1.786748
                    iteration 300 / 1500: loss 1.646337
                    iteration 400 / 1500: loss 1.582530
                    iteration 500 / 1500: loss 1.654073
                    iteration 600 / 1500: loss 1.554874
                    iteration 700 / 1500: loss 1.582179
                    iteration 800 / 1500: loss 1.504040
                    iteration 900 / 1500: loss 1.530995
                    iteration 1000 / 1500: loss 1.380532
                    iteration 1100 / 1500: loss 1.427156
                    iteration 1200 / 1500: loss 1.367041
                    iteration 1300 / 1500: loss 1.386233
                    iteration 1400 / 1500: loss 1.414279
                    0.001 0.05 100 1500 0.5405510204081633 0.497
                    iteration 0 / 1500: loss 2.302847
                    iteration 100 / 1500: loss 1.966210
                    iteration 200 / 1500: loss 1.674648
                    iteration 300 / 1500: loss 1.729593
                    iteration 400 / 1500: loss 1.574419
                    iteration 500 / 1500: loss 1.481668
                    iteration 600 / 1500: loss 1.368150
                    iteration 700 / 1500: loss 1.493285
                    iteration 800 / 1500: loss 1.412429
                    iteration 900 / 1500: loss 1.333159
                    iteration 1000 / 1500: loss 1.441580
                    iteration 1100 / 1500: loss 1.249393
                    iteration 1200 / 1500: loss 1.349668
                    iteration 1300 / 1500: loss 1.327294
                    iteration 1400 / 1500: loss 1.356886
                    0.001 0.05 175 1500 0.5495102040816326 0.497
                    iteration 0 / 1500: loss 2.302617
                    iteration 100 / 1500: loss 1.917738
                    iteration 200 / 1500: loss 1.851924
                    iteration 300 / 1500: loss 1.875052
                    iteration 400 / 1500: loss 1.806317
                    iteration 500 / 1500: loss 1.736647
                    iteration 600 / 1500: loss 1.591002
                    iteration 700 / 1500: loss 1.720169
                    iteration 800 / 1500: loss 1.754130
                    iteration 900 / 1500: loss 1.633410
                    iteration 1000 / 1500: loss 1.710909
                    iteration 1100 / 1500: loss 1.708574
                    iteration 1200 / 1500: loss 1.554480
                    iteration 1300 / 1500: loss 1.648432
                    iteration 1400 / 1500: loss 1.567624
                    0.001 0.1 10 1500 0.4213265306122449 0.417
                    iteration 0 / 1500: loss 2.302718
                    iteration 100 / 1500: loss 1.841435
                    iteration 200 / 1500: loss 1.860598
                    iteration 300 / 1500: loss 1.603514
```

```
iteration 400 / 1500: loss 1.618434
iteration 500 / 1500: loss 1.584280
iteration 600 / 1500: loss 1.585440
iteration 700 / 1500: loss 1.693593
iteration 800 / 1500: loss 1.336018
iteration 900 / 1500: loss 1.612018
iteration 1000 / 1500: loss 1.462693
iteration 1100 / 1500: loss 1.392181
iteration 1200 / 1500: loss 1.390081
iteration 1300 / 1500: loss 1.335786
iteration 1400 / 1500: loss 1.398952
0.001 0.1 50 1500 0.5190204081632653 0.481
iteration 0 / 1500: loss 2.302791
iteration 100 / 1500: loss 1.917598
iteration 200 / 1500: loss 1.704846
iteration 300 / 1500: loss 1.706951
iteration 400 / 1500: loss 1.648095
iteration 500 / 1500: loss 1.481745
iteration 600 / 1500: loss 1.570443
iteration 700 / 1500: loss 1.376391
iteration 800 / 1500: loss 1.520935
iteration 900 / 1500: loss 1.539532
iteration 1000 / 1500: loss 1.446267
iteration 1100 / 1500: loss 1.448221
iteration 1200 / 1500: loss 1.573629
iteration 1300 / 1500: loss 1.329988
iteration 1400 / 1500: loss 1.447993
0.001 0.1 75 1500 0.5269183673469388 0.498
iteration 0 / 1500: loss 2.302895
iteration 100 / 1500: loss 1.907553
iteration 200 / 1500: loss 1.702193
iteration 300 / 1500: loss 1.703395
iteration 400 / 1500: loss 1.717506
iteration 500 / 1500: loss 1.478786
iteration 600 / 1500: loss 1.542609
iteration 700 / 1500: loss 1.496846
iteration 800 / 1500: loss 1.526187
iteration 900 / 1500: loss 1.516049
iteration 1000 / 1500: loss 1.536404
iteration 1100 / 1500: loss 1.527520
iteration 1200 / 1500: loss 1.461063
iteration 1300 / 1500: loss 1.367854
iteration 1400 / 1500: loss 1.506590
0.001 0.1 100 1500 0.5365102040816326 0.507
iteration 0 / 1500: loss 2.303150
iteration 100 / 1500: loss 1.885639
iteration 200 / 1500: loss 1.813416
iteration 300 / 1500: loss 1.666411
iteration 400 / 1500: loss 1.612956
iteration 500 / 1500: loss 1.676996
iteration 600 / 1500: loss 1.599660
iteration 700 / 1500: loss 1.481737
iteration 800 / 1500: loss 1.528940
iteration 900 / 1500: loss 1.540344
iteration 1000 / 1500: loss 1.607985
iteration 1100 / 1500: loss 1.354850
iteration 1200 / 1500: loss 1.434934
iteration 1300 / 1500: loss 1.355213
iteration 1400 / 1500: loss 1.407208
0.001 0.1 175 1500 0.5428775510204081 0.489
```

```
iteration 0 / 1500: loss 2.302650
iteration 100 / 1500: loss 2.018231
iteration 200 / 1500: loss 1.856572
iteration 300 / 1500: loss 1.741457
iteration 400 / 1500: loss 1.780761
iteration 500 / 1500: loss 1.731473
iteration 600 / 1500: loss 1.710156
iteration 700 / 1500: loss 1.703554
iteration 800 / 1500: loss 1.688609
iteration 900 / 1500: loss 1.661758
iteration 1000 / 1500: loss 1.770494
iteration 1100 / 1500: loss 1.707810
iteration 1200 / 1500: loss 1.653869
iteration 1300 / 1500: loss 1.697022
iteration 1400 / 1500: loss 1.798931
0.001 0.2 10 1500 0.4159591836734694 0.425
iteration 0 / 1500: loss 2.302897
iteration 100 / 1500: loss 1.995605
iteration 200 / 1500: loss 1.868293
iteration 300 / 1500: loss 1.733241
iteration 400 / 1500: loss 1.559577
iteration 500 / 1500: loss 1.638549
iteration 600 / 1500: loss 1.636789
iteration 700 / 1500: loss 1.582128
iteration 800 / 1500: loss 1.404489
iteration 900 / 1500: loss 1.597191
iteration 1000 / 1500: loss 1.374982
iteration 1100 / 1500: loss 1.451304
iteration 1200 / 1500: loss 1.534912
iteration 1300 / 1500: loss 1.494886
iteration 1400 / 1500: loss 1.464489
0.001 0.2 50 1500 0.5098571428571429 0.488
iteration 0 / 1500: loss 2.303066
iteration 100 / 1500: loss 1.877479
iteration 200 / 1500: loss 1.714940
iteration 300 / 1500: loss 1.709760
iteration 400 / 1500: loss 1.646792
iteration 500 / 1500: loss 1.508114
iteration 600 / 1500: loss 1.543537
iteration 700 / 1500: loss 1.528517
iteration 800 / 1500: loss 1.441495
iteration 900 / 1500: loss 1.487699
iteration 1000 / 1500: loss 1.485014
iteration 1100 / 1500: loss 1.560177
iteration 1200 / 1500: loss 1.313585
iteration 1300 / 1500: loss 1.475316
iteration 1400 / 1500: loss 1.410356
0.001 0.2 75 1500 0.5180204081632653 0.513
iteration 0 / 1500: loss 2.303239
iteration 100 / 1500: loss 1.976057
iteration 200 / 1500: loss 1.809361
iteration 300 / 1500: loss 1.703631
iteration 400 / 1500: loss 1.640818
iteration 500 / 1500: loss 1.573741
iteration 600 / 1500: loss 1.509390
iteration 700 / 1500: loss 1.654938
iteration 800 / 1500: loss 1.464060
iteration 900 / 1500: loss 1.473062
iteration 1000 / 1500: loss 1.635358
iteration 1100 / 1500: loss 1.414466
```

```
iteration 1200 / 1500: loss 1.515283
iteration 1300 / 1500: loss 1.471828
iteration 1400 / 1500: loss 1.539441
0.001 0.2 100 1500 0.5273061224489796 0.491
iteration 0 / 1500: loss 2.303660
iteration 100 / 1500: loss 1.951181
iteration 200 / 1500: loss 1.703394
iteration 300 / 1500: loss 1.710064
iteration 400 / 1500: loss 1.624007
iteration 500 / 1500: loss 1.541224
iteration 600 / 1500: loss 1.593130
iteration 700 / 1500: loss 1.616081
iteration 800 / 1500: loss 1.523449
iteration 900 / 1500: loss 1.544994
iteration 1000 / 1500: loss 1.505442
iteration 1100 / 1500: loss 1.393242
iteration 1200 / 1500: loss 1.613921
iteration 1300 / 1500: loss 1.345963
iteration 1400 / 1500: loss 1.427957
0.001 0.2 175 1500 0.542530612244898 0.503
iteration 0 / 1500: loss 2.302586
iteration 100 / 1500: loss 1.936013
iteration 200 / 1500: loss 1.755611
iteration 300 / 1500: loss 1.622788
iteration 400 / 1500: loss 1.752205
iteration 500 / 1500: loss 1.800847
iteration 600 / 1500: loss 1.715860
iteration 700 / 1500: loss 1.652939
iteration 800 / 1500: loss 1.733479
iteration 900 / 1500: loss 1.613664
iteration 1000 / 1500: loss 1.691526
iteration 1100 / 1500: loss 1.625219
iteration 1200 / 1500: loss 1.715489
iteration 1300 / 1500: loss 1.786024
iteration 1400 / 1500: loss 1.800226
0.002 0.01 10 1500 0.4246122448979592 0.422
iteration 0 / 1500: loss 2.302588
iteration 100 / 1500: loss 1.679137
iteration 200 / 1500: loss 1.630740
iteration 300 / 1500: loss 1.661055
iteration 400 / 1500: loss 1.610664
iteration 500 / 1500: loss 1.483693
iteration 600 / 1500: loss 1.500198
iteration 700 / 1500: loss 1.481397
iteration 800 / 1500: loss 1.338846
iteration 900 / 1500: loss 1.473960
iteration 1000 / 1500: loss 1.355679
iteration 1100 / 1500: loss 1.369272
iteration 1200 / 1500: loss 1.408348
iteration 1300 / 1500: loss 1.371862
iteration 1400 / 1500: loss 1.186500
0.002 0.01 50 1500 0.517265306122449 0.469
iteration 0 / 1500: loss 2.302636
iteration 100 / 1500: loss 1.842706
iteration 200 / 1500: loss 1.633716
iteration 300 / 1500: loss 1.693347
iteration 400 / 1500: loss 1.457477
iteration 500 / 1500: loss 1.627703
iteration 600 / 1500: loss 1.453924
iteration 700 / 1500: loss 1.417954
```

```
iteration 800 / 1500: loss 1.548755
iteration 900 / 1500: loss 1.461433
iteration 1000 / 1500: loss 1.583802
iteration 1100 / 1500: loss 1.376772
iteration 1200 / 1500: loss 1.404984
iteration 1300 / 1500: loss 1.330388
iteration 1400 / 1500: loss 1.407420
0.002 0.01 75 1500 0.517673469387755 0.477
iteration 0 / 1500: loss 2.302608
iteration 100 / 1500: loss 1.868025
iteration 200 / 1500: loss 1.804395
iteration 300 / 1500: loss 1.536416
iteration 400 / 1500: loss 1.633291
iteration 500 / 1500: loss 1.572034
iteration 600 / 1500: loss 1.486844
iteration 700 / 1500: loss 1.302225
iteration 800 / 1500: loss 1.537931
iteration 900 / 1500: loss 1.487552
iteration 1000 / 1500: loss 1.450825
iteration 1100 / 1500: loss 1.414719
iteration 1200 / 1500: loss 1.431065
iteration 1300 / 1500: loss 1.364014
iteration 1400 / 1500: loss 1.233104
0.002 0.01 100 1500 0.5637142857142857 0.506
iteration 0 / 1500: loss 2.302644
iteration 100 / 1500: loss 1.742485
iteration 200 / 1500: loss 1.827878
iteration 300 / 1500: loss 1.612123
iteration 400 / 1500: loss 1.633973
iteration 500 / 1500: loss 1.438447
iteration 600 / 1500: loss 1.668466
iteration 700 / 1500: loss 1.469488
iteration 800 / 1500: loss 1.363785
iteration 900 / 1500: loss 1.484550
iteration 1000 / 1500: loss 1.366088
iteration 1100 / 1500: loss 1.573756
iteration 1200 / 1500: loss 1.280131
iteration 1300 / 1500: loss 1.324836
iteration 1400 / 1500: loss 1.276357
0.002 0.01 175 1500 0.5568775510204081 0.481
iteration 0 / 1500: loss 2.302609
iteration 100 / 1500: loss 1.810241
iteration 200 / 1500: loss 1.797240
iteration 300 / 1500: loss 1.670123
iteration 400 / 1500: loss 1.743107
iteration 500 / 1500: loss 1.653194
iteration 600 / 1500: loss 1.561071
iteration 700 / 1500: loss 1.683172
iteration 800 / 1500: loss 1.683133
iteration 900 / 1500: loss 1.698611
iteration 1000 / 1500: loss 1.599151
iteration 1100 / 1500: loss 1.647735
iteration 1200 / 1500: loss 1.655624
iteration 1300 / 1500: loss 1.562890
iteration 1400 / 1500: loss 1.720932
0.002 0.05 10 1500 0.4134081632653061 0.406
iteration 0 / 1500: loss 2.302684
iteration 100 / 1500: loss 1.811452
iteration 200 / 1500: loss 1.659404
iteration 300 / 1500: loss 1.747122
```

```
iteration 400 / 1500: loss 1.544560
iteration 500 / 1500: loss 1.559885
iteration 600 / 1500: loss 1.626393
iteration 700 / 1500: loss 1.676859
iteration 800 / 1500: loss 1.510586
iteration 900 / 1500: loss 1.324762
iteration 1000 / 1500: loss 1.380596
iteration 1100 / 1500: loss 1.536937
iteration 1200 / 1500: loss 1.522462
iteration 1300 / 1500: loss 1.410302
iteration 1400 / 1500: loss 1.358331
0.002 0.05 50 1500 0.5162244897959184 0.479
iteration 0 / 1500: loss 2.302696
iteration 100 / 1500: loss 1.867827
iteration 200 / 1500: loss 1.669973
iteration 300 / 1500: loss 1.542844
iteration 400 / 1500: loss 1.583350
iteration 500 / 1500: loss 1.588674
iteration 600 / 1500: loss 1.535836
iteration 700 / 1500: loss 1.568247
iteration 800 / 1500: loss 1.555164
iteration 900 / 1500: loss 1.457909
iteration 1000 / 1500: loss 1.454219
iteration 1100 / 1500: loss 1.371683
iteration 1200 / 1500: loss 1.487892
iteration 1300 / 1500: loss 1.415991
iteration 1400 / 1500: loss 1.340583
0.002 0.05 75 1500 0.5375510204081633 0.489
iteration 0 / 1500: loss 2.302787
iteration 100 / 1500: loss 1.892947
iteration 200 / 1500: loss 1.635978
iteration 300 / 1500: loss 1.646842
iteration 400 / 1500: loss 1.534368
iteration 500 / 1500: loss 1.545403
iteration 600 / 1500: loss 1.375824
iteration 700 / 1500: loss 1.549551
iteration 800 / 1500: loss 1.477621
iteration 900 / 1500: loss 1.435314
iteration 1000 / 1500: loss 1.391520
iteration 1100 / 1500: loss 1.473445
iteration 1200 / 1500: loss 1.516047
iteration 1300 / 1500: loss 1.259968
iteration 1400 / 1500: loss 1.312495
0.002 0.05 100 1500 0.5521020408163265 0.485
iteration 0 / 1500: loss 2.302870
iteration 100 / 1500: loss 1.873280
iteration 200 / 1500: loss 1.767165
iteration 300 / 1500: loss 1.650776
iteration 400 / 1500: loss 1.430998
iteration 500 / 1500: loss 1.497013
iteration 600 / 1500: loss 1.558588
iteration 700 / 1500: loss 1.475155
iteration 800 / 1500: loss 1.466894
iteration 900 / 1500: loss 1.460159
iteration 1000 / 1500: loss 1.316684
iteration 1100 / 1500: loss 1.356986
iteration 1200 / 1500: loss 1.472925
iteration 1300 / 1500: loss 1.425580
iteration 1400 / 1500: loss 1.333032
0.002 0.05 175 1500 0.5592857142857143 0.503
```

```
iteration 0 / 1500: loss 2.302612
iteration 100 / 1500: loss 1.962913
iteration 200 / 1500: loss 1.808733
iteration 300 / 1500: loss 1.878951
iteration 400 / 1500: loss 1.672078
iteration 500 / 1500: loss 1.762464
iteration 600 / 1500: loss 1.743507
iteration 700 / 1500: loss 1.651068
iteration 800 / 1500: loss 1.681621
iteration 900 / 1500: loss 1.563291
iteration 1000 / 1500: loss 1.687142
iteration 1100 / 1500: loss 1.567468
iteration 1200 / 1500: loss 1.637531
iteration 1300 / 1500: loss 1.742697
iteration 1400 / 1500: loss 1.639406
0.002 0.1 10 1500 0.42718367346938774 0.406
iteration 0 / 1500: loss 2.302753
iteration 100 / 1500: loss 1.827849
iteration 200 / 1500: loss 1.547716
iteration 300 / 1500: loss 1.523356
iteration 400 / 1500: loss 1.568197
iteration 500 / 1500: loss 1.607688
iteration 600 / 1500: loss 1.462818
iteration 700 / 1500: loss 1.763992
iteration 800 / 1500: loss 1.476784
iteration 900 / 1500: loss 1.549522
iteration 1000 / 1500: loss 1.468769
iteration 1100 / 1500: loss 1.385158
iteration 1200 / 1500: loss 1.494301
iteration 1300 / 1500: loss 1.491146
iteration 1400 / 1500: loss 1.336829
0.002 0.1 50 1500 0.5305102040816326 0.504
iteration 0 / 1500: loss 2.302799
iteration 100 / 1500: loss 1.769530
iteration 200 / 1500: loss 1.618694
iteration 300 / 1500: loss 1.578498
iteration 400 / 1500: loss 1.744103
iteration 500 / 1500: loss 1.518144
iteration 600 / 1500: loss 1.475301
iteration 700 / 1500: loss 1.607258
iteration 800 / 1500: loss 1.402574
iteration 900 / 1500: loss 1.651034
iteration 1000 / 1500: loss 1.413401
iteration 1100 / 1500: loss 1.466483
iteration 1200 / 1500: loss 1.483266
iteration 1300 / 1500: loss 1.339728
iteration 1400 / 1500: loss 1.412421
0.002 0.1 75 1500 0.5206938775510204 0.483
iteration 0 / 1500: loss 2.302903
iteration 100 / 1500: loss 1.705539
iteration 200 / 1500: loss 1.632057
iteration 300 / 1500: loss 1.637294
iteration 400 / 1500: loss 1.659235
iteration 500 / 1500: loss 1.461950
iteration 600 / 1500: loss 1.506024
iteration 700 / 1500: loss 1.522659
iteration 800 / 1500: loss 1.507466
iteration 900 / 1500: loss 1.639763
iteration 1000 / 1500: loss 1.619040
iteration 1100 / 1500: loss 1.600849
```

```
            iteration 1200 / 1500: loss 1.304731
            iteration 1300 / 1500: loss 1.346517
            iteration 1400 / 1500: loss 1.325150
            0.002 0.1 100 1500 0.5467142857142857 0.496
            iteration 0 / 1500: loss 2.303174
            iteration 100 / 1500: loss 1.755206
            iteration 200 / 1500: loss 1.765400
            iteration 300 / 1500: loss 1.551595
            iteration 400 / 1500: loss 1.547892
            iteration 500 / 1500: loss 1.487882
            iteration 600 / 1500: loss 1.540200
            iteration 700 / 1500: loss 1.536664
            iteration 800 / 1500: loss 1.499859
            iteration 900 / 1500: loss 1.480225
            iteration 1000 / 1500: loss 1.545118
            iteration 1100 / 1500: loss 1.448452
            iteration 1200 / 1500: loss 1.412277
            iteration 1300 / 1500: loss 1.500328
            iteration 1400 / 1500: loss 1.453195
            0.002 0.1 175 1500 0.5447755102040817 0.493
            iteration 0 / 1500: loss 2.302655
            iteration 100 / 1500: loss 1.833127
            iteration 200 / 1500: loss 1.876331
            iteration 300 / 1500: loss 1.813361
            iteration 400 / 1500: loss 1.816237
            iteration 500 / 1500: loss 1.697454
            iteration 600 / 1500: loss 1.706733
            iteration 700 / 1500: loss 1.608339
            iteration 800 / 1500: loss 1.676824
            iteration 900 / 1500: loss 1.750544
            iteration 1000 / 1500: loss 1.647144
            iteration 1100 / 1500: loss 1.625029
            iteration 1200 / 1500: loss 1.714080
            iteration 1300 / 1500: loss 1.729352
            iteration 1400 / 1500: loss 1.754859
            0.002 0.2 10 1500 0.42220408163265305 0.403
            iteration 0 / 1500: loss 2.302890
            iteration 100 / 1500: loss 1.745245
            iteration 200 / 1500: loss 1.629616
            iteration 300 / 1500: loss 1.639269
            iteration 400 / 1500: loss 1.671483
            iteration 500 / 1500: loss 1.554921
            iteration 600 / 1500: loss 1.676845
            iteration 700 / 1500: loss 1.627795
            iteration 800 / 1500: loss 1.528215
            iteration 900 / 1500: loss 1.557568
            iteration 1000 / 1500: loss 1.552441
            iteration 1100 / 1500: loss 1.495685
            iteration 1200 / 1500: loss 1.427848
            iteration 1300 / 1500: loss 1.704368
            iteration 1400 / 1500: loss 1.481764
            0.002 0.2 50 1500 0.5090204081632653 0.495
            iteration 0 / 1500: loss 2.303092
            iteration 100 / 1500: loss 1.787655
            iteration 200 / 1500: loss 1.645438
            iteration 300 / 1500: loss 1.621044
            iteration 400 / 1500: loss 1.728610
            iteration 500 / 1500: loss 1.548264
            iteration 600 / 1500: loss 1.506396
            iteration 700 / 1500: loss 1.517344
```

```
iteration 800 / 1500: loss 1.668029
iteration 900 / 1500: loss 1.520800
iteration 1000 / 1500: loss 1.510949
iteration 1100 / 1500: loss 1.594933
iteration 1200 / 1500: loss 1.344070
iteration 1300 / 1500: loss 1.471513
iteration 1400 / 1500: loss 1.557916
0.002 0.2 75 1500 0.5399183673469388 0.513
iteration 0 / 1500: loss 2.303173
iteration 100 / 1500: loss 1.698156
iteration 200 / 1500: loss 1.695287
iteration 300 / 1500: loss 1.515822
iteration 400 / 1500: loss 1.564219
iteration 500 / 1500: loss 1.485791
iteration 600 / 1500: loss 1.504949
iteration 700 / 1500: loss 1.473937
iteration 800 / 1500: loss 1.526825
iteration 900 / 1500: loss 1.483404
iteration 1000 / 1500: loss 1.530143
iteration 1100 / 1500: loss 1.457893
iteration 1200 / 1500: loss 1.588844
iteration 1300 / 1500: loss 1.538501
iteration 1400 / 1500: loss 1.450776
0.002 0.2 100 1500 0.5317142857142857 0.487
iteration 0 / 1500: loss 2.303691
iteration 100 / 1500: loss 1.759024
iteration 200 / 1500: loss 1.608597
iteration 300 / 1500: loss 1.734630
iteration 400 / 1500: loss 1.635697
iteration 500 / 1500: loss 1.599272
iteration 600 / 1500: loss 1.439598
iteration 700 / 1500: loss 1.572509
iteration 800 / 1500: loss 1.545757
iteration 900 / 1500: loss 1.560142
iteration 1000 / 1500: loss 1.447020
iteration 1100 / 1500: loss 1.504310
iteration 1200 / 1500: loss 1.674203
iteration 1300 / 1500: loss 1.345916
iteration 1400 / 1500: loss 1.273366
0.002 0.2 175 1500 0.547469387755102 0.526
lr 1.000000e-03 reg 1.000000e-02 hidden_size 1.000000e+01 num_training_epochs 1.50000
0e+03 train accuracy: 0.419816 val accuracy: 0.405000
lr 1.000000e-03 reg 1.000000e-02 hidden_size 5.000000e+01 num_training_epochs 1.50000
0e+03 train accuracy: 0.515755 val accuracy: 0.478000
lr 1.000000e-03 reg 1.000000e-02 hidden_size 7.500000e+01 num_training_epochs 1.50000
0e+03 train accuracy: 0.534939 val accuracy: 0.494000
lr 1.000000e-03 reg 1.000000e-02 hidden_size 1.000000e+02 num_training_epochs 1.50000
0e+03 train accuracy: 0.532592 val accuracy: 0.488000
lr 1.000000e-03 reg 1.000000e-02 hidden_size 1.750000e+02 num_training_epochs 1.50000
0e+03 train accuracy: 0.544857 val accuracy: 0.479000
lr 1.000000e-03 reg 5.000000e-02 hidden_size 1.000000e+01 num_training_epochs 1.50000
0e+03 train accuracy: 0.417490 val accuracy: 0.393000
lr 1.000000e-03 reg 5.000000e-02 hidden_size 5.000000e+01 num_training_epochs 1.50000
0e+03 train accuracy: 0.517980 val accuracy: 0.495000
lr 1.000000e-03 reg 5.000000e-02 hidden_size 7.500000e+01 num_training_epochs 1.50000
0e+03 train accuracy: 0.526327 val accuracy: 0.478000
lr 1.000000e-03 reg 5.000000e-02 hidden_size 1.000000e+02 num_training_epochs 1.50000
0e+03 train accuracy: 0.540551 val accuracy: 0.497000
lr 1.000000e-03 reg 5.000000e-02 hidden_size 1.750000e+02 num_training_epochs 1.50000
0e+03 train accuracy: 0.549510 val accuracy: 0.497000
```

```
lr 1.000000e-03 reg 1.000000e-01 hidden_size 1.000000e+01 num_training_epochs 1.50000
0e+03 train accuracy: 0.421327 val accuracy: 0.417000
lr 1.000000e-03 reg 1.000000e-01 hidden_size 5.000000e+01 num_training_epochs 1.50000
0e+03 train accuracy: 0.519020 val accuracy: 0.481000
lr 1.000000e-03 reg 1.000000e-01 hidden_size 7.500000e+01 num_training_epochs 1.50000
0e+03 train accuracy: 0.526918 val accuracy: 0.498000
lr 1.000000e-03 reg 1.000000e-01 hidden_size 1.000000e+02 num_training_epochs 1.50000
0e+03 train accuracy: 0.536510 val accuracy: 0.507000
lr 1.000000e-03 reg 1.000000e-01 hidden_size 1.750000e+02 num_training_epochs 1.50000
0e+03 train accuracy: 0.542878 val accuracy: 0.489000
lr 1.000000e-03 reg 2.000000e-01 hidden_size 1.000000e+01 num_training_epochs 1.50000
0e+03 train accuracy: 0.415959 val accuracy: 0.425000
lr 1.000000e-03 reg 2.000000e-01 hidden_size 5.000000e+01 num_training_epochs 1.50000
0e+03 train accuracy: 0.509857 val accuracy: 0.488000
lr 1.000000e-03 reg 2.000000e-01 hidden_size 7.500000e+01 num_training_epochs 1.50000
0e+03 train accuracy: 0.518020 val accuracy: 0.513000
lr 1.000000e-03 reg 2.000000e-01 hidden_size 1.000000e+02 num_training_epochs 1.50000
0e+03 train accuracy: 0.527306 val accuracy: 0.491000
lr 1.000000e-03 reg 2.000000e-01 hidden_size 1.750000e+02 num_training_epochs 1.50000
0e+03 train accuracy: 0.542531 val accuracy: 0.503000
lr 2.000000e-03 reg 1.000000e-02 hidden_size 1.000000e+01 num_training_epochs 1.50000
0e+03 train accuracy: 0.424612 val accuracy: 0.422000
lr 2.000000e-03 reg 1.000000e-02 hidden_size 5.000000e+01 num_training_epochs 1.50000
0e+03 train accuracy: 0.517265 val accuracy: 0.469000
lr 2.000000e-03 reg 1.000000e-02 hidden_size 7.500000e+01 num_training_epochs 1.50000
0e+03 train accuracy: 0.517673 val accuracy: 0.477000
lr 2.000000e-03 reg 1.000000e-02 hidden_size 1.000000e+02 num_training_epochs 1.50000
0e+03 train accuracy: 0.563714 val accuracy: 0.506000
lr 2.000000e-03 reg 1.000000e-02 hidden_size 1.750000e+02 num_training_epochs 1.50000
0e+03 train accuracy: 0.556878 val accuracy: 0.481000
lr 2.000000e-03 reg 5.000000e-02 hidden_size 1.000000e+01 num_training_epochs 1.50000
0e+03 train accuracy: 0.413408 val accuracy: 0.406000
lr 2.000000e-03 reg 5.000000e-02 hidden_size 5.000000e+01 num_training_epochs 1.50000
0e+03 train accuracy: 0.516224 val accuracy: 0.479000
lr 2.000000e-03 reg 5.000000e-02 hidden_size 7.500000e+01 num_training_epochs 1.50000
0e+03 train accuracy: 0.537551 val accuracy: 0.489000
lr 2.000000e-03 reg 5.000000e-02 hidden_size 1.000000e+02 num_training_epochs 1.50000
0e+03 train accuracy: 0.552102 val accuracy: 0.485000
lr 2.000000e-03 reg 5.000000e-02 hidden_size 1.750000e+02 num_training_epochs 1.50000
0e+03 train accuracy: 0.559286 val accuracy: 0.503000
lr 2.000000e-03 reg 1.000000e-01 hidden_size 1.000000e+01 num_training_epochs 1.50000
0e+03 train accuracy: 0.427184 val accuracy: 0.406000
lr 2.000000e-03 reg 1.000000e-01 hidden_size 5.000000e+01 num_training_epochs 1.50000
0e+03 train accuracy: 0.530510 val accuracy: 0.504000
lr 2.000000e-03 reg 1.000000e-01 hidden_size 7.500000e+01 num_training_epochs 1.50000
0e+03 train accuracy: 0.520694 val accuracy: 0.483000
lr 2.000000e-03 reg 1.000000e-01 hidden_size 1.000000e+02 num_training_epochs 1.50000
0e+03 train accuracy: 0.546714 val accuracy: 0.496000
lr 2.000000e-03 reg 1.000000e-01 hidden_size 1.750000e+02 num_training_epochs 1.50000
0e+03 train accuracy: 0.544776 val accuracy: 0.493000
lr 2.000000e-03 reg 2.000000e-01 hidden_size 1.000000e+01 num_training_epochs 1.50000
0e+03 train accuracy: 0.422204 val accuracy: 0.403000
lr 2.000000e-03 reg 2.000000e-01 hidden_size 5.000000e+01 num_training_epochs 1.50000
0e+03 train accuracy: 0.509020 val accuracy: 0.495000
lr 2.000000e-03 reg 2.000000e-01 hidden_size 7.500000e+01 num_training_epochs 1.50000
0e+03 train accuracy: 0.539918 val accuracy: 0.513000
lr 2.000000e-03 reg 2.000000e-01 hidden_size 1.000000e+02 num_training_epochs 1.50000
0e+03 train accuracy: 0.531714 val accuracy: 0.487000
lr 2.000000e-03 reg 2.000000e-01 hidden_size 1.750000e+02 num_training_epochs 1.50000
```

```
0e+03 train accuracy: 0.547469 val accuracy: 0.526000
best validation accuracy achieved during cross-validation: 0.526000
```

In [ ]:
```python
# visualize the weights of the best network
show_net_weights(best_net)
```


Run on the test set

When you are done experimenting, you should evaluate your final trained network on the test set; you should get above 48%.

In [ ]:
```python
test_acc = (best_net.predict(X_test) == y_test).mean()
print('Test accuracy: ', test_acc)
```

Test accuracy: 0.514

Inline Question

Now that you have trained a Neural Network classifier, you may find that your testing accuracy is much lower than the training accuracy. In what ways can we decrease this gap? Select all that apply.

1. Train on a larger dataset.
2. Add more hidden units.
3. Increase the regularization strength.
4. None of the above.

Your answer: 1 and 3.

Your explanation:

1. Train on a larger dataset: Training on a larger dataset allows the model to generalize better, this is because it allows the model to see more diverse examples and prevents it form memorizing the training data or in other words it prevents the model from overfitting. This can reduce the gap between training and testing accuracy.

2. Add more hidden units: Increasing the number of hidden units increases the models complexity, this can allow the model to learn the noise in the dataset and in turn increase overfitting. Hence, this can increase the gap between the training and testing accuracy.

3. Increase the regularization strength: By increasing regularization, we reduce the models tendency to overfit by encouraging it to find simpler patterns in the dataset and therefore increase the models generalization capabilities. This can help decrease the gap between the training and testing accuracy.

```
In [ ]:  # 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/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/$FOLDERNAME/cs6353/datasets/
         !bash get_datasets.sh
         %cd /content/drive/My\ Drive/$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/assignment2/cs6353/datasets
--2024-09-30 00:42:53--  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'

cifar-10-python.tar 100%[===================>] 162.60M  51.8MB/s    in 3.3s

2024-09-30 00:42:57 (49.8 MB/s) - 'cifar-10-python.tar.gz' saved [170498071/17049807
1]

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/assignment2
Requirement already satisfied: anyio==3.7.1 in /usr/local/lib/python3.10/dist-package
s (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//colab_
requirements.txt (line 1)) (3.7.1)
Collecting appnope==0.1.3 (from -r /content/drive/My Drive/CS6353/Assignments/assignm
ent2/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/assignment
2//colab_requirements.txt (line 3)) (23.1.0)
Requirement already satisfied: argon2-cffi-bindings==21.2.0 in /usr/local/lib/python
3.10/dist-packages (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/as
signment2//colab_requirements.txt (line 4)) (21.2.0)
Collecting arrow==1.2.3 (from -r /content/drive/My Drive/CS6353/Assignments/assignmen
t2/assignment2//colab_requirements.txt (line 5))
  Downloading arrow-1.2.3-py3-none-any.whl.metadata (6.9 kB)
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nment2/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/assig
nment2/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/assignme
nt2/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/assignme
nt2/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-pack
ages (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//col
ab_requirements.txt (line 10)) (0.2.0)
Collecting beautifulsoup4==4.12.2 (from -r /content/drive/My Drive/CS6353/Assignment
s/assignment2/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/assignme
nt2/assignment2//colab_requirements.txt (line 12))
  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/ass
ignment2/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/assignmen
t2/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/Assignme
nts/assignment2/assignment2//colab_requirements.txt (line 15))
  Downloading charset_normalizer-3.2.0-cp310-cp310-manylinux_2_17_x86_64.manylinux201
4_x86_64.whl.metadata (31 kB)
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2/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/assig
nment2/assignment2//colab_requirements.txt (line 17))
  Downloading contourpy-1.1.0-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.
whl.metadata (5.7 kB)
Collecting cycler==0.11.0 (from -r /content/drive/My Drive/CS6353/Assignments/assignm
ent2/assignment2//colab_requirements.txt (line 18))
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Collecting debugpy==1.6.7.post1 (from -r /content/drive/My Drive/CS6353/Assignments/a
ssignment2/assignment2//colab_requirements.txt (line 19))
  Downloading debugpy-1.6.7.post1-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86
_64.whl.metadata (1.1 kB)
Requirement already satisfied: decorator<=5.0 in /usr/local/lib/python3.10/dist-packa
ges (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//cola
b_requirements.txt (line 20)) (4.4.2)
Requirement already satisfied: defusedxml==0.7.1 in /usr/local/lib/python3.10/dist-pa
ckages (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//c
olab_requirements.txt (line 21)) (0.7.1)
Collecting executing==1.2.0 (from -r /content/drive/My Drive/CS6353/Assignments/assig
nment2/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/Assignment
s/assignment2/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/assi
gnment2/assignment2//colab_requirements.txt (line 24))
  Downloading fonttools-4.42.1-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_6
4.whl.metadata (150 kB)
                ──────────────────────────────────── 151.0/151.0 kB 4.9 MB/s eta 0:00:00
Collecting fqdn==1.5.1 (from -r /content/drive/My Drive/CS6353/Assignments/assignment
2/assignment2//colab_requirements.txt (line 25))
  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/
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/assign
ment2/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-pac
kages (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//co
lab_requirements.txt (line 28)) (5.5.6)
Requirement already satisfied: ipython<=7.34.0 in /usr/local/lib/python3.10/dist-pack
ages (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//col
ab_requirements.txt (line 29)) (7.34.0)
Collecting isoduration==20.11.0 (from -r /content/drive/My Drive/CS6353/Assignments/a
ssignment2/assignment2//colab_requirements.txt (line 30))
  Downloading isoduration-20.11.0-py3-none-any.whl.metadata (5.7 kB)

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Collecting jedi==0.19.0 (from -r /content/drive/My Drive/CS6353/Assignments/assignmen
t2/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/assignme
nt2/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/assignme
nt2/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/assig
nment2/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/ass
ignment2/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/CS635
3/Assignments/assignment2/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/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/ass
ignment2/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-p
ackages (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//
colab_requirements.txt (line 39)) (6.1.12)
Collecting jupyter_core==5.3.1 (from -r /content/drive/My Drive/CS6353/Assignments/as
signment2/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 Drive/CS6353/Assignments/
assignment2/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/As
signments/assignment2/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/assi
gnment2/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/Assignm
ents/assignment2/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/Assignme
nts/assignment2/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/assi
gnment2/assignment2//colab_requirements.txt (line 46))
  Downloading kiwisolver-1.4.5-cp310-cp310-manylinux_2_12_x86_64.manylinux2010_x86_6
4.whl.metadata (6.4 kB)
Collecting MarkupSafe==2.1.3 (from -r /content/drive/My Drive/CS6353/Assignments/assi
gnment2/assignment2//colab_requirements.txt (line 47))
  Downloading MarkupSafe-2.1.3-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_6
4.whl.metadata (3.0 kB)
Collecting matplotlib==3.7.2 (from -r /content/drive/My Drive/CS6353/Assignments/assi
gnment2/assignment2//colab_requirements.txt (line 48))
  Downloading matplotlib-3.7.2-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_6
4.whl.metadata (5.6 kB)
Collecting matplotlib-inline==0.1.6 (from -r /content/drive/My Drive/CS6353/Assignmen
ts/assignment2/assignment2//colab_requirements.txt (line 49))
  Downloading matplotlib_inline-0.1.6-py3-none-any.whl.metadata (2.8 kB)
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Collecting mistune==3.0.1 (from -r /content/drive/My Drive/CS6353/Assignments/assignm
ent2/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/assign
ment2/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/assig
nment2/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/assign
ment2/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/as
signment2/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/a
ssignment2/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 Drive/CS6353/Assignments/assi
gnment2/assignment2//colab_requirements.txt (line 56))
  Downloading numpy-1.23.5-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.wh
l.metadata (2.3 kB)
Collecting overrides==7.4.0 (from -r /content/drive/My Drive/CS6353/Assignments/assig
nment2/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/assign
ment2/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/assignme
nt2/assignment2//colab_requirements.txt (line 59))
  Downloading pandas-1.5.3-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.wh
l.metadata (11 kB)
Collecting pandocfilters==1.5.0 (from -r /content/drive/My Drive/CS6353/Assignments/a
ssignment2/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/assignmen
t2/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/assignm
ent2/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-p
ackages (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//
colab_requirements.txt (line 63)) (0.7.5)
Collecting Pillow==10.0.0 (from -r /content/drive/My Drive/CS6353/Assignments/assignm
ent2/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/a
ssignment2/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/Assignme
nts/assignment2/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/Assignment
s/assignment2/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-packag
es (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//colab
_requirements.txt (line 68)) (5.9.5)
Requirement already satisfied: ptyprocess==0.7.0 in /usr/local/lib/python3.10/dist-pa
```

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ckages (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//c
olab_requirements.txt (line 69)) (0.7.0)
Collecting pure-eval==0.2.2 (from -r /content/drive/My Drive/CS6353/Assignments/assig
nment2/assignment2//colab_requirements.txt (line 70))
  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/assign
ment2/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/assig
nment2/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/assig
nment2/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/di
st-packages (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignmen
t2//colab_requirements.txt (line 74)) (2.8.2)
Collecting python-json-logger==2.0.7 (from -r /content/drive/My Drive/CS6353/Assignme
nts/assignment2/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/assignmen
t2/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/assignme
nt2/assignment2//colab_requirements.txt (line 77))
  Downloading PyYAML-6.0.1-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.wh
l.metadata (2.1 kB)
Requirement already satisfied: pyzmq<25 in /usr/local/lib/python3.10/dist-packages (f
rom -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//colab_requ
irements.txt (line 78)) (24.0.1)
Collecting referencing==0.30.2 (from -r /content/drive/My Drive/CS6353/Assignments/as
signment2/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/assig
nment2/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/Assignmen
ts/assignment2/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/Assignmen
ts/assignment2/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/assignm
ent2/assignment2//colab_requirements.txt (line 83))
  Downloading rpds_py-0.9.2-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.wh
l.metadata (3.7 kB)
Collecting scipy==1.11.2 (from -r /content/drive/My Drive/CS6353/Assignments/assignme
nt2/assignment2//colab_requirements.txt (line 84))
  Downloading scipy-1.11.2-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.wh
l.metadata (59 kB)
                                       ━━━━━━━━━━━━━━━━━━━━━━ 59.1/59.1 kB 3.1 MB/s eta 0:00:00
Collecting seaborn==0.12.2 (from -r /content/drive/My Drive/CS6353/Assignments/assign
ment2/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/assi
gnment2/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/assignment2//colab_re
quirements.txt (line 87)) (1.16.0)
```

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Collecting sniffio==1.3.0 (from -r /content/drive/My Drive/CS6353/Assignments/assignm
ent2/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/assig
nment2/assignment2//colab_requirements.txt (line 89))
  Downloading soupsieve-2.4.1-py3-none-any.whl.metadata (4.7 kB)
Collecting stack-data==0.6.2 (from -r /content/drive/My Drive/CS6353/Assignments/assi
gnment2/assignment2//colab_requirements.txt (line 90))
  Downloading stack_data-0.6.2-py3-none-any.whl.metadata (18 kB)
Collecting terminado==0.17.1 (from -r /content/drive/My Drive/CS6353/Assignments/assi
gnment2/assignment2//colab_requirements.txt (line 91))
  Downloading terminado-0.17.1-py3-none-any.whl.metadata (5.9 kB)
Collecting tinycss2==1.2.1 (from -r /content/drive/My Drive/CS6353/Assignments/assign
ment2/assignment2//colab_requirements.txt (line 92))
  Downloading tinycss2-1.2.1-py3-none-any.whl.metadata (3.0 kB)
Collecting tornado<=6.3.2 (from -r /content/drive/My Drive/CS6353/Assignments/assignm
ent2/assignment2//colab_requirements.txt (line 93))
  Downloading tornado-6.3.2-cp38-abi3-manylinux_2_5_x86_64.manylinux1_x86_64.manylinu
x_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/assig
nment2/assignment2//colab_requirements.txt (line 94))
  Downloading traitlets-5.9.0-py3-none-any.whl.metadata (10 kB)
Collecting tzdata==2023.3 (from -r /content/drive/My Drive/CS6353/Assignments/assignm
ent2/assignment2//colab_requirements.txt (line 95))
  Downloading tzdata-2023.3-py2.py3-none-any.whl.metadata (1.4 kB)
Collecting uri-template==1.3.0 (from -r /content/drive/My Drive/CS6353/Assignments/as
signment2/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/assignm
ent2/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/assignm
ent2/assignment2//colab_requirements.txt (line 98))
  Downloading wcwidth-0.2.6-py2.py3-none-any.whl.metadata (11 kB)
Collecting webcolors==1.13 (from -r /content/drive/My Drive/CS6353/Assignments/assign
ment2/assignment2//colab_requirements.txt (line 99))
  Downloading webcolors-1.13-py3-none-any.whl.metadata (2.6 kB)
Requirement already satisfied: webencodings==0.5.1 in /usr/local/lib/python3.10/dist-
packages (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment
2//colab_requirements.txt (line 100)) (0.5.1)
Collecting websocket-client==1.6.2 (from -r /content/drive/My Drive/CS6353/Assignment
s/assignment2/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-packa
ges (from anyio==3.7.1->-r /content/drive/My Drive/CS6353/Assignments/assignment2/ass
ignment2//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/a
ssignment2/assignment2//colab_requirements.txt (line 7)) (4.12.2)
Collecting jupyter_client<8.0 (from -r /content/drive/My Drive/CS6353/Assignments/ass
ignment2/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/assignme
nt2//colab_requirements.txt (line 43)) (2.0.1)
Requirement already satisfied: ipython-genutils in /usr/local/lib/python3.10/dist-pac
kages (from ipykernel<=5.5.6->-r /content/drive/My Drive/CS6353/Assignments/assignmen
t2/assignment2//colab_requirements.txt (line 28)) (0.2.0)
Requirement already satisfied: setuptools>=18.5 in /usr/local/lib/python3.10/dist-pac
kages (from ipython<=7.34.0->-r /content/drive/My Drive/CS6353/Assignments/assignment
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                    2/assignment2//colab_requirements.txt (line 29)) (71.0.4)
                    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/a
                    ssignment2//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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                    Downloading attrs-23.1.0-py3-none-any.whl (61 kB)
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                    l (300 kB)
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                    4.whl (3.0 MB)
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                    hl (4.5 MB)
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hl (1.6 MB)
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hl (11.6 MB)
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Downloading pandocfilters-1.5.0-py2.py3-none-any.whl (8.7 kB)
Downloading parso-0.8.3-py2.py3-none-any.whl (100 kB)
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Downloading sniffio-1.3.0-py3-none-any.whl (10 kB)
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Downloading stack_data-0.6.2-py3-none-any.whl (24 kB)
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Downloading tinycss2-1.2.1-py3-none-any.whl (21 kB)
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(17.1 MB)
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(12.1 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)
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Installing collected packages: wcwidth, pytz, pure-eval, json5, fastjsonschema, execu
ting, appnope, websocket-client, webcolors, urllib3, uri-template, tzdata, traitlets,
tornado, tinycss2, soupsieve, sniffio, Send2Trash, rpds-py, rfc3986-validator, rfc333
9-validator, PyYAML, python-json-logger, pyparsing, Pygments, pycparser, prompt-toolk
it, prometheus-client, platformdirs, Pillow, pexpect, parso, pandocfilters, packagin
g, overrides, numpy, nest-asyncio, mistune, MarkupSafe, kiwisolver, jupyterlab-pygmen
ts, jsonpointer, idna, fqdn, fonttools, debugpy, cycler, charset-normalizer, certifi,
bleach, Babel, attrs, async-lru, asttokens, terminado, stack-data, scipy, requests, r
eferencing, pandas, matplotlib-inline, jupyter_core, Jinja2, jedi, imageio, contourp
y, comm, cffi, beautifulsoup4, arrow, matplotlib, jupyter_server_terminals, jupyter_c
lient, jsonschema-specifications, isoduration, seaborn, jsonschema, nbformat, nbclien
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er-lsp, jupyterlab
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      Successfully uninstalled wcwidth-0.2.13
  Attempting uninstall: pytz
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    Uninstalling pytz-2024.2:
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    Uninstalling fastjsonschema-2.20.0:
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  Attempting uninstall: websocket-client
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      Attempting uninstall: traitlets
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      Attempting uninstall: tornado
        Found existing installation: tornado 6.3.3
        Uninstalling tornado-6.3.3:
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      Attempting uninstall: tinycss2
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      Attempting uninstall: soupsieve
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      Attempting uninstall: sniffio
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      Attempting uninstall: pycparser
        Found existing installation: pycparser 2.22
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      Attempting uninstall: prompt-toolkit
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     Attempting uninstall: platformdirs
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           Successfully uninstalled platformdirs-4.3.6
     Attempting uninstall: Pillow
         Found existing installation: pillow 10.4.0
         Uninstalling pillow-10.4.0:
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     Attempting uninstall: pexpect
         Found existing installation: pexpect 4.9.0
         Uninstalling pexpect-4.9.0:
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     Attempting uninstall: parso
         Found existing installation: parso 0.8.4
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     Attempting uninstall: pandocfilters
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     Attempting uninstall: packaging
         Found existing installation: packaging 24.1
         Uninstalling packaging-24.1:
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     Attempting uninstall: numpy
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         Uninstalling numpy-1.26.4:
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     Attempting uninstall: nest-asyncio
         Found existing installation: nest-asyncio 1.6.0
         Uninstalling nest-asyncio-1.6.0:
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     Attempting uninstall: mistune
         Found existing installation: mistune 0.8.4
         Uninstalling mistune-0.8.4:
           Successfully uninstalled mistune-0.8.4
     Attempting uninstall: MarkupSafe
         Found existing installation: MarkupSafe 2.1.5
         Uninstalling MarkupSafe-2.1.5:
           Successfully uninstalled MarkupSafe-2.1.5
     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: idna
         Found existing installation: idna 3.10
         Uninstalling idna-3.10:
           Successfully uninstalled idna-3.10
     Attempting uninstall: fonttools
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        Uninstalling fonttools-4.53.1:
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      Attempting uninstall: debugpy
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      Attempting uninstall: cycler
        Found existing installation: cycler 0.12.1
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      Attempting uninstall: charset-normalizer
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      Attempting uninstall: certifi
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        Found existing installation: babel 2.16.0
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      Attempting uninstall: attrs
        Found existing installation: attrs 24.2.0
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        Found existing installation: terminado 0.18.1
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          Successfully uninstalled terminado-0.18.1
      Attempting uninstall: scipy
        Found existing installation: scipy 1.13.1
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      Attempting uninstall: requests
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      Attempting uninstall: referencing
        Found existing installation: referencing 0.35.1
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      Attempting uninstall: pandas
        Found existing installation: pandas 2.1.4
        Uninstalling pandas-2.1.4:
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      Attempting uninstall: matplotlib-inline
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        Uninstalling 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
```

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      Attempting uninstall: imageio
        Found existing installation: imageio 2.35.1
        Uninstalling imageio-2.35.1:
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      Attempting uninstall: contourpy
        Found existing installation: contourpy 1.3.0
        Uninstalling contourpy-1.3.0:
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      Attempting uninstall: cffi
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      Attempting uninstall: beautifulsoup4
        Found existing installation: beautifulsoup4 4.12.3
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      Attempting uninstall: matplotlib
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        Uninstalling jsonschema-specifications-2023.12.1:
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        Found existing installation: seaborn 0.13.1
        Uninstalling seaborn-0.13.1:
          Successfully uninstalled seaborn-0.13.1
      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 0.10.0
        Uninstalling nbclient-0.10.0:
          Successfully uninstalled nbclient-0.10.0
      Attempting uninstall: nbconvert
        Found existing installation: nbconvert 6.5.4
        Uninstalling nbconvert-6.5.4:
          Successfully uninstalled nbconvert-6.5.4
      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 package
```

```
s that are installed. This behaviour is the source of the following dependency confli
cts.
albucore 0.0.16 requires numpy>=1.24, but you have numpy 1.23.5 which is incompatibl
e.
albumentations 1.4.15 requires numpy>=1.24.4, but you have numpy 1.23.5 which is inco
mpatible.
bigframes 1.18.0 requires numpy>=1.24.0, but you have numpy 1.23.5 which is incompati
ble.
bokeh 3.4.3 requires contourpy>=1.2, but you have contourpy 1.1.0 which is incompatib
le.
chex 0.1.86 requires numpy>=1.24.1, but you have numpy 1.23.5 which is incompatible.
cudf-cu12 24.4.1 requires pandas<2.2.2dev0,>=2.0, but you have pandas 1.5.3 which is
incompatible.
google-colab 1.0.0 requires pandas==2.1.4, but you have pandas 1.5.3 which is incompa
tible.
google-colab 1.0.0 requires requests==2.32.3, but you have requests 2.31.0 which is i
ncompatible.
google-colab 1.0.0 requires tornado==6.3.3, but you have tornado 6.3.2 which is incom
patible.
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.
mizani 0.11.4 requires pandas>=2.1.0, but you have pandas 1.5.3 which is incompatibl
e.
pandas-stubs 2.1.4.231227 requires numpy>=1.26.0; python_version < "3.13", but you ha
ve numpy 1.23.5 which is incompatible.
plotnine 0.13.6 requires pandas<3.0.0,>=2.1.0, but you have pandas 1.5.3 which is inc
ompatible.
scikit-image 0.24.0 requires imageio>=2.33, but you have imageio 2.31.1 which is inco
mpatible.
xarray 2024.9.0 requires numpy>=1.24, but you have numpy 1.23.5 which is incompatibl
e.
xarray 2024.9.0 requires pandas>=2.1, but you have pandas 1.5.3 which is incompatibl
e.
Successfully installed Babel-2.12.1 Jinja2-3.1.2 MarkupSafe-2.1.3 Pillow-10.0.0 PyYAM
L-6.0.1 Pygments-2.16.1 Send2Trash-1.8.2 appnope-0.1.3 arrow-1.2.3 asttokens-2.2.1 as
ync-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 im
ageio-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 jupy
ter_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 platfor
mdirs-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 request
s-2.31.0 rfc3339-validator-0.1.4 rfc3986-validator-0.1.1 rpds-py-0.9.2 scipy-1.11.2 s
eaborn-0.12.2 sniffio-1.3.0 soupsieve-2.4.1 stack-data-0.6.2 terminado-0.17.1 tinycss
2-1.2.1 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
```

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.

```
In [ ]:  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
```

Load data

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

```
In [ ]:  from cs6353.features import color_histogram_hsv, hog_feature

         def get_CIFAR10_data(cifar10_dir='cs6353/datasets/cifar-10-batches-py', num_training=4
             # 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
         try:
            del X_train, y_train
            del X_test, y_test
            print('Clear previously loaded data.')
         except:
            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'
################################################################################
#                            END  OF  YOUR  CODE                              #
################################################################################


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

Extract Features

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

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

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

```
In [ ]:   from cs6353.features import *

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

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

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

          # Preprocessing: Add a bias dimension
          X_train_feats = np.hstack([X_train_feats, np.ones((X_train_feats.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
Done extracting features for 12000 / 49000 images
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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
```

Train SVM on features

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

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

```python
from cs6353.classifiers.linear_classifier import LinearSVM

learning_rates = [1e-7, 1e-5, 1e-4, 1e-3, 2e-7]
regularization_strengths = [1, 1e-1, 2e-1, 5e-1, 1e-2, 5e3]

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:

        svm = LinearSVM()

        svm.train(X_train_feats, y_train, learning_rate=lr, reg=reg, num_iters=1500, v

        y_train_pred = svm.predict(X_train_feats)
        y_val_pred = svm.predict(X_val_feats)

        train_results = y_train_pred == y_train
        y_train_accuracy = np.mean(train_results)

        val_results = y_val_pred == y_val
        y_val_accuracy = np.mean(val_results)

        results[(lr, reg)] = (y_train_accuracy, y_val_accuracy)

        if y_val_accuracy > best_val:
            best_val = y_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)
```

```
iteration 0 / 1500: loss 9.013532
iteration 100 / 1500: loss 9.005905
iteration 200 / 1500: loss 8.999067
iteration 300 / 1500: loss 9.010873
iteration 400 / 1500: loss 9.012125
iteration 500 / 1500: loss 9.006480
iteration 600 / 1500: loss 8.998394
iteration 700 / 1500: loss 8.996802
iteration 800 / 1500: loss 9.006092
iteration 900 / 1500: loss 9.003871
iteration 1000 / 1500: loss 9.006651
iteration 1100 / 1500: loss 8.996429
iteration 1200 / 1500: loss 8.993661
iteration 1300 / 1500: loss 8.987182
iteration 1400 / 1500: loss 8.996445
iteration 0 / 1500: loss 9.000013
iteration 100 / 1500: loss 8.995990
iteration 200 / 1500: loss 8.995294
iteration 300 / 1500: loss 9.006803
iteration 400 / 1500: loss 8.995009
iteration 500 / 1500: loss 8.987107
iteration 600 / 1500: loss 8.997460
iteration 700 / 1500: loss 8.988426
iteration 800 / 1500: loss 8.985681
iteration 900 / 1500: loss 8.985636
iteration 1000 / 1500: loss 8.997433
iteration 1100 / 1500: loss 8.983115
iteration 1200 / 1500: loss 8.985105
iteration 1300 / 1500: loss 8.993259
iteration 1400 / 1500: loss 8.993054
iteration 0 / 1500: loss 8.998570
iteration 100 / 1500: loss 8.971324
iteration 200 / 1500: loss 8.997724
iteration 300 / 1500: loss 8.982777
iteration 400 / 1500: loss 9.003107
iteration 500 / 1500: loss 9.001476
iteration 600 / 1500: loss 8.985405
iteration 700 / 1500: loss 8.991129
iteration 800 / 1500: loss 8.990169
iteration 900 / 1500: loss 8.989853
iteration 1000 / 1500: loss 8.997513
iteration 1100 / 1500: loss 8.988364
iteration 1200 / 1500: loss 8.981983
iteration 1300 / 1500: loss 8.979658
iteration 1400 / 1500: loss 8.979322
iteration 0 / 1500: loss 9.020787
iteration 100 / 1500: loss 9.017756
iteration 200 / 1500: loss 9.009067
iteration 300 / 1500: loss 9.011930
iteration 400 / 1500: loss 9.004455
iteration 500 / 1500: loss 9.006968
iteration 600 / 1500: loss 9.006946
iteration 700 / 1500: loss 9.016035
iteration 800 / 1500: loss 9.002542
iteration 900 / 1500: loss 9.010131
iteration 1000 / 1500: loss 9.013870
iteration 1100 / 1500: loss 8.998080
iteration 1200 / 1500: loss 9.014795
iteration 1300 / 1500: loss 8.999988
iteration 1400 / 1500: loss 9.006232
```

```
iteration 0 / 1500: loss 8.992293
iteration 100 / 1500: loss 9.003871
iteration 200 / 1500: loss 9.006667
iteration 300 / 1500: loss 9.015637
iteration 400 / 1500: loss 9.006338
iteration 500 / 1500: loss 9.003154
iteration 600 / 1500: loss 8.997350
iteration 700 / 1500: loss 8.987879
iteration 800 / 1500: loss 8.982116
iteration 900 / 1500: loss 9.008131
iteration 1000 / 1500: loss 8.997903
iteration 1100 / 1500: loss 9.001313
iteration 1200 / 1500: loss 8.991351
iteration 1300 / 1500: loss 8.986975
iteration 1400 / 1500: loss 8.998100
iteration 0 / 1500: loss 16.445010
iteration 100 / 1500: loss 15.079379
iteration 200 / 1500: loss 13.983241
iteration 300 / 1500: loss 13.073827
iteration 400 / 1500: loss 12.329636
iteration 500 / 1500: loss 11.722678
iteration 600 / 1500: loss 11.230366
iteration 700 / 1500: loss 10.831539
iteration 800 / 1500: loss 10.500262
iteration 900 / 1500: loss 10.227037
iteration 1000 / 1500: loss 10.003496
iteration 1100 / 1500: loss 9.818231
iteration 1200 / 1500: loss 9.669582
iteration 1300 / 1500: loss 9.547674
iteration 1400 / 1500: loss 9.450321
iteration 0 / 1500: loss 8.975145
iteration 100 / 1500: loss 8.896527
iteration 200 / 1500: loss 8.834638
iteration 300 / 1500: loss 8.775904
iteration 400 / 1500: loss 8.694544
iteration 500 / 1500: loss 8.638067
iteration 600 / 1500: loss 8.543439
iteration 700 / 1500: loss 8.438022
iteration 800 / 1500: loss 8.474371
iteration 900 / 1500: loss 8.313164
iteration 1000 / 1500: loss 8.326647
iteration 1100 / 1500: loss 8.207184
iteration 1200 / 1500: loss 8.155812
iteration 1300 / 1500: loss 8.114780
iteration 1400 / 1500: loss 8.070573
iteration 0 / 1500: loss 9.000184
iteration 100 / 1500: loss 8.944632
iteration 200 / 1500: loss 8.865356
iteration 300 / 1500: loss 8.796489
iteration 400 / 1500: loss 8.741757
iteration 500 / 1500: loss 8.624932
iteration 600 / 1500: loss 8.556358
iteration 700 / 1500: loss 8.498920
iteration 800 / 1500: loss 8.419911
iteration 900 / 1500: loss 8.314671
iteration 1000 / 1500: loss 8.255334
iteration 1100 / 1500: loss 8.307116
iteration 1200 / 1500: loss 8.238507
iteration 1300 / 1500: loss 8.061611
iteration 1400 / 1500: loss 8.078579
```

```
iteration 0 / 1500: loss 8.979697
iteration 100 / 1500: loss 8.907890
iteration 200 / 1500: loss 8.843051
iteration 300 / 1500: loss 8.779633
iteration 400 / 1500: loss 8.724639
iteration 500 / 1500: loss 8.623214
iteration 600 / 1500: loss 8.565148
iteration 700 / 1500: loss 8.506168
iteration 800 / 1500: loss 8.374103
iteration 900 / 1500: loss 8.340418
iteration 1000 / 1500: loss 8.256675
iteration 1100 / 1500: loss 8.258177
iteration 1200 / 1500: loss 8.175996
iteration 1300 / 1500: loss 7.962400
iteration 1400 / 1500: loss 8.021050
iteration 0 / 1500: loss 8.990459
iteration 100 / 1500: loss 8.937378
iteration 200 / 1500: loss 8.837634
iteration 300 / 1500: loss 8.780671
iteration 400 / 1500: loss 8.691435
iteration 500 / 1500: loss 8.618017
iteration 600 / 1500: loss 8.532597
iteration 700 / 1500: loss 8.531897
iteration 800 / 1500: loss 8.381886
iteration 900 / 1500: loss 8.282453
iteration 1000 / 1500: loss 8.281086
iteration 1100 / 1500: loss 8.268697
iteration 1200 / 1500: loss 8.118914
iteration 1300 / 1500: loss 8.096367
iteration 1400 / 1500: loss 7.982691
iteration 0 / 1500: loss 8.993519
iteration 100 / 1500: loss 8.950262
iteration 200 / 1500: loss 8.859969
iteration 300 / 1500: loss 8.815860
iteration 400 / 1500: loss 8.701106
iteration 500 / 1500: loss 8.628908
iteration 600 / 1500: loss 8.587463
iteration 700 / 1500: loss 8.503385
iteration 800 / 1500: loss 8.444351
iteration 900 / 1500: loss 8.376981
iteration 1000 / 1500: loss 8.224956
iteration 1100 / 1500: loss 8.142255
iteration 1200 / 1500: loss 8.129663
iteration 1300 / 1500: loss 8.132952
iteration 1400 / 1500: loss 7.974167
iteration 0 / 1500: loss 16.745371
iteration 100 / 1500: loss 8.997250
iteration 200 / 1500: loss 8.996818
iteration 300 / 1500: loss 8.997674
iteration 400 / 1500: loss 8.996294
iteration 500 / 1500: loss 8.996386
iteration 600 / 1500: loss 8.996522
iteration 700 / 1500: loss 8.997703
iteration 800 / 1500: loss 8.996459
iteration 900 / 1500: loss 8.996154
iteration 1000 / 1500: loss 8.996721
iteration 1100 / 1500: loss 8.997367
iteration 1200 / 1500: loss 8.996567
iteration 1300 / 1500: loss 8.996511
iteration 1400 / 1500: loss 8.997005
```

```
iteration 0 / 1500: loss 8.998873
iteration 100 / 1500: loss 8.211621
iteration 200 / 1500: loss 7.751104
iteration 300 / 1500: loss 7.285559
iteration 400 / 1500: loss 6.727619
iteration 500 / 1500: loss 6.215527
iteration 600 / 1500: loss 6.037269
iteration 700 / 1500: loss 5.224562
iteration 800 / 1500: loss 5.672082
iteration 900 / 1500: loss 5.022154
iteration 1000 / 1500: loss 5.708719
iteration 1100 / 1500: loss 5.580490
iteration 1200 / 1500: loss 5.462514
iteration 1300 / 1500: loss 5.353922
iteration 1400 / 1500: loss 4.728410
iteration 0 / 1500: loss 9.013173
iteration 100 / 1500: loss 8.322357
iteration 200 / 1500: loss 7.673927
iteration 300 / 1500: loss 6.920234
iteration 400 / 1500: loss 6.174442
iteration 500 / 1500: loss 6.117465
iteration 600 / 1500: loss 5.860024
iteration 700 / 1500: loss 5.276261
iteration 800 / 1500: loss 4.905651
iteration 900 / 1500: loss 4.950825
iteration 1000 / 1500: loss 5.097077
iteration 1100 / 1500: loss 5.222958
iteration 1200 / 1500: loss 4.436571
iteration 1300 / 1500: loss 5.081638
iteration 1400 / 1500: loss 4.419436
iteration 0 / 1500: loss 8.992998
iteration 100 / 1500: loss 8.298625
iteration 200 / 1500: loss 7.548628
iteration 300 / 1500: loss 6.753199
iteration 400 / 1500: loss 6.312741
iteration 500 / 1500: loss 6.110861
iteration 600 / 1500: loss 5.904919
iteration 700 / 1500: loss 5.725787
iteration 800 / 1500: loss 5.394149
iteration 900 / 1500: loss 4.801168
iteration 1000 / 1500: loss 5.104601
iteration 1100 / 1500: loss 4.775095
iteration 1200 / 1500: loss 4.671688
iteration 1300 / 1500: loss 4.504473
iteration 1400 / 1500: loss 4.531796
iteration 0 / 1500: loss 8.983970
iteration 100 / 1500: loss 8.133287
iteration 200 / 1500: loss 7.559833
iteration 300 / 1500: loss 6.921541
iteration 400 / 1500: loss 6.128608
iteration 500 / 1500: loss 6.026581
iteration 600 / 1500: loss 5.617900
iteration 700 / 1500: loss 6.094780
iteration 800 / 1500: loss 5.027963
iteration 900 / 1500: loss 5.152269
iteration 1000 / 1500: loss 5.017656
iteration 1100 / 1500: loss 4.984861
iteration 1200 / 1500: loss 4.733104
iteration 1300 / 1500: loss 4.907429
iteration 1400 / 1500: loss 4.971434
```

```
iteration 0 / 1500: loss 8.998810
iteration 100 / 1500: loss 8.317201
iteration 200 / 1500: loss 7.486032
iteration 300 / 1500: loss 6.671095
iteration 400 / 1500: loss 6.339828
iteration 500 / 1500: loss 6.070355
iteration 600 / 1500: loss 5.434010
iteration 700 / 1500: loss 5.379509
iteration 800 / 1500: loss 5.075093
iteration 900 / 1500: loss 5.058158
iteration 1000 / 1500: loss 4.610936
iteration 1100 / 1500: loss 4.607124
iteration 1200 / 1500: loss 4.881768
iteration 1300 / 1500: loss 4.450071
iteration 1400 / 1500: loss 4.446012
iteration 0 / 1500: loss 16.844162
iteration 100 / 1500: loss 9.000173
iteration 200 / 1500: loss 8.999393
iteration 300 / 1500: loss 9.000491
iteration 400 / 1500: loss 9.000237
iteration 500 / 1500: loss 8.999904
iteration 600 / 1500: loss 8.999456
iteration 700 / 1500: loss 9.001182
iteration 800 / 1500: loss 8.999983
iteration 900 / 1500: loss 9.001006
iteration 1000 / 1500: loss 9.000078
iteration 1100 / 1500: loss 9.000734
iteration 1200 / 1500: loss 8.998640
iteration 1300 / 1500: loss 8.998972
iteration 1400 / 1500: loss 8.999032
iteration 0 / 1500: loss 9.008268
iteration 100 / 1500: loss 5.530308
iteration 200 / 1500: loss 5.125856
iteration 300 / 1500: loss 4.659448
iteration 400 / 1500: loss 4.841204
iteration 500 / 1500: loss 4.636888
iteration 600 / 1500: loss 4.829179
iteration 700 / 1500: loss 4.889966
iteration 800 / 1500: loss 4.827435
iteration 900 / 1500: loss 4.832629
iteration 1000 / 1500: loss 4.838947
iteration 1100 / 1500: loss 5.397892
iteration 1200 / 1500: loss 4.713454
iteration 1300 / 1500: loss 4.880191
iteration 1400 / 1500: loss 5.267529
iteration 0 / 1500: loss 8.986719
iteration 100 / 1500: loss 5.197790
iteration 200 / 1500: loss 4.804896
iteration 300 / 1500: loss 3.842488
iteration 400 / 1500: loss 3.791836
iteration 500 / 1500: loss 3.936980
iteration 600 / 1500: loss 3.780975
iteration 700 / 1500: loss 3.537026
iteration 800 / 1500: loss 3.145250
iteration 900 / 1500: loss 3.205181
iteration 1000 / 1500: loss 3.314481
iteration 1100 / 1500: loss 3.523786
iteration 1200 / 1500: loss 2.974993
iteration 1300 / 1500: loss 3.377697
iteration 1400 / 1500: loss 3.346372
```

```
iteration 0 / 1500: loss 9.012271
iteration 100 / 1500: loss 4.683300
iteration 200 / 1500: loss 4.280253
iteration 300 / 1500: loss 3.925573
iteration 400 / 1500: loss 3.610590
iteration 500 / 1500: loss 3.916129
iteration 600 / 1500: loss 3.948670
iteration 700 / 1500: loss 3.941106
iteration 800 / 1500: loss 3.777270
iteration 900 / 1500: loss 3.651549
iteration 1000 / 1500: loss 3.778945
iteration 1100 / 1500: loss 4.017471
iteration 1200 / 1500: loss 3.920450
iteration 1300 / 1500: loss 3.418260
iteration 1400 / 1500: loss 3.672257
iteration 0 / 1500: loss 8.996609
iteration 100 / 1500: loss 4.958472
iteration 200 / 1500: loss 4.414333
iteration 300 / 1500: loss 4.408473
iteration 400 / 1500: loss 3.975846
iteration 500 / 1500: loss 4.201985
iteration 600 / 1500: loss 4.546119
iteration 700 / 1500: loss 4.396723
iteration 800 / 1500: loss 4.417406
iteration 900 / 1500: loss 4.000232
iteration 1000 / 1500: loss 4.158696
iteration 1100 / 1500: loss 4.500879
iteration 1200 / 1500: loss 3.922109
iteration 1300 / 1500: loss 4.458384
iteration 1400 / 1500: loss 4.117051
iteration 0 / 1500: loss 8.995200
iteration 100 / 1500: loss 5.119368
iteration 200 / 1500: loss 3.472156
iteration 300 / 1500: loss 3.869788
iteration 400 / 1500: loss 3.524658
iteration 500 / 1500: loss 3.423991
iteration 600 / 1500: loss 3.785522
iteration 700 / 1500: loss 3.408188
iteration 800 / 1500: loss 3.604609
iteration 900 / 1500: loss 3.154217
iteration 1000 / 1500: loss 3.066422
iteration 1100 / 1500: loss 3.364834
iteration 1200 / 1500: loss 3.153840
iteration 1300 / 1500: loss 3.339472
iteration 1400 / 1500: loss 2.779781
iteration 0 / 1500: loss 16.692660
iteration 100 / 1500: loss 5432540045339055261188022265079119509313939275896963849584
45602781671745156375543745747131261253503845372367118290928340562602514026533784562 10
42624186980340480902223605728575654833704277114 88.000000
iteration 200 / 1500: loss inf
iteration 300 / 1500: loss inf
iteration 400 / 1500: loss nan
```

```
/content/drive/MyDrive/CS6353/Assignments/assignment2/assignment2/cs6353/classifiers/
linear_svm.py:100: RuntimeWarning: overflow encountered in scalar multiply
  loss += reg * np.sum(W * W)
/usr/local/lib/python3.10/dist-packages/numpy/core/fromnumeric.py:88: RuntimeWarning:
overflow encountered in reduce

/content/drive/MyDrive/CS6353/Assignments/assignment2/assignment2/cs6353/classifiers/
linear_svm.py:100: RuntimeWarning: overflow encountered in multiply
  loss += reg * np.sum(W * W)
/content/drive/MyDrive/CS6353/Assignments/assignment2/assignment2/cs6353/classifiers/
linear_svm.py:125: RuntimeWarning: overflow encountered in multiply
  dW += 2 * reg * W
/content/drive/MyDrive/CS6353/Assignments/assignment2/assignment2/cs6353/classifiers/
linear_classifier.py:70: RuntimeWarning: invalid value encountered in subtract
  self.W -= learning_rate * grad
```

```
iteration 500 / 1500: loss nan
iteration 600 / 1500: loss nan
iteration 700 / 1500: loss nan
iteration 800 / 1500: loss nan
iteration 900 / 1500: loss nan
iteration 1000 / 1500: loss nan
iteration 1100 / 1500: loss nan
iteration 1200 / 1500: loss nan
iteration 1300 / 1500: loss nan
iteration 1400 / 1500: loss nan
iteration 0 / 1500: loss 8.979867
iteration 100 / 1500: loss 8.996251
iteration 200 / 1500: loss 9.001369
iteration 300 / 1500: loss 8.980656
iteration 400 / 1500: loss 8.981561
iteration 500 / 1500: loss 8.991502
iteration 600 / 1500: loss 8.959770
iteration 700 / 1500: loss 8.987205
iteration 800 / 1500: loss 8.983566
iteration 900 / 1500: loss 8.986715
iteration 1000 / 1500: loss 8.981800
iteration 1100 / 1500: loss 8.968632
iteration 1200 / 1500: loss 8.956905
iteration 1300 / 1500: loss 8.979529
iteration 1400 / 1500: loss 8.977704
iteration 0 / 1500: loss 8.998422
iteration 100 / 1500: loss 8.985798
iteration 200 / 1500: loss 8.977414
iteration 300 / 1500: loss 8.982007
iteration 400 / 1500: loss 8.981535
iteration 500 / 1500: loss 8.980430
iteration 600 / 1500: loss 8.981968
iteration 700 / 1500: loss 8.979893
iteration 800 / 1500: loss 8.966357
iteration 900 / 1500: loss 8.966229
iteration 1000 / 1500: loss 8.976326
iteration 1100 / 1500: loss 8.984724
iteration 1200 / 1500: loss 8.966523
iteration 1300 / 1500: loss 8.988293
iteration 1400 / 1500: loss 8.977714
iteration 0 / 1500: loss 9.011928
iteration 100 / 1500: loss 9.015683
iteration 200 / 1500: loss 9.009162
iteration 300 / 1500: loss 8.990739
iteration 400 / 1500: loss 9.006050
iteration 500 / 1500: loss 9.002419
iteration 600 / 1500: loss 8.984172
iteration 700 / 1500: loss 9.013493
iteration 800 / 1500: loss 8.995792
iteration 900 / 1500: loss 9.005634
iteration 1000 / 1500: loss 8.984671
iteration 1100 / 1500: loss 8.989461
iteration 1200 / 1500: loss 8.991261
iteration 1300 / 1500: loss 8.983193
iteration 1400 / 1500: loss 8.981880
iteration 0 / 1500: loss 8.985978
iteration 100 / 1500: loss 9.013909
iteration 200 / 1500: loss 9.004129
iteration 300 / 1500: loss 8.995814
iteration 400 / 1500: loss 8.986354
```

```
iteration 500 / 1500: loss 8.992970
iteration 600 / 1500: loss 8.992309
iteration 700 / 1500: loss 8.989405
iteration 800 / 1500: loss 8.986906
iteration 900 / 1500: loss 8.982426
iteration 1000 / 1500: loss 8.975887
iteration 1100 / 1500: loss 8.983723
iteration 1200 / 1500: loss 8.980348
iteration 1300 / 1500: loss 8.975027
iteration 1400 / 1500: loss 8.960443
iteration 0 / 1500: loss 9.001468
iteration 100 / 1500: loss 9.014731
iteration 200 / 1500: loss 8.998339
iteration 300 / 1500: loss 8.998015
iteration 400 / 1500: loss 8.990683
iteration 500 / 1500: loss 8.991826
iteration 600 / 1500: loss 8.984588
iteration 700 / 1500: loss 8.984822
iteration 800 / 1500: loss 8.990561
iteration 900 / 1500: loss 8.981084
iteration 1000 / 1500: loss 8.977509
iteration 1100 / 1500: loss 8.970272
iteration 1200 / 1500: loss 8.982036
iteration 1300 / 1500: loss 8.977331
iteration 1400 / 1500: loss 8.988174
iteration 0 / 1500: loss 17.012696
iteration 100 / 1500: loss 14.360557
iteration 200 / 1500: loss 12.591737
iteration 300 / 1500: loss 11.406741
iteration 400 / 1500: loss 10.606751
iteration 500 / 1500: loss 10.077585
iteration 600 / 1500: loss 9.722681
iteration 700 / 1500: loss 9.484263
iteration 800 / 1500: loss 9.323231
iteration 900 / 1500: loss 9.214641
iteration 1000 / 1500: loss 9.141867
iteration 1100 / 1500: loss 9.093606
iteration 1200 / 1500: loss 9.060933
iteration 1300 / 1500: loss 9.040592
iteration 1400 / 1500: loss 9.026970
lr 1.000000e-07 reg 1.000000e-02 train accuracy: 0.111816 val accuracy: 0.100000
lr 1.000000e-07 reg 1.000000e-01 train accuracy: 0.122163 val accuracy: 0.113000
lr 1.000000e-07 reg 2.000000e-01 train accuracy: 0.126980 val accuracy: 0.123000
lr 1.000000e-07 reg 5.000000e-01 train accuracy: 0.088551 val accuracy: 0.082000
lr 1.000000e-07 reg 1.000000e+00 train accuracy: 0.105776 val accuracy: 0.114000
lr 1.000000e-07 reg 5.000000e+03 train accuracy: 0.147490 val accuracy: 0.138000
lr 2.000000e-07 reg 1.000000e-02 train accuracy: 0.141531 val accuracy: 0.139000
lr 2.000000e-07 reg 1.000000e-01 train accuracy: 0.141959 val accuracy: 0.156000
lr 2.000000e-07 reg 2.000000e-01 train accuracy: 0.126653 val accuracy: 0.116000
lr 2.000000e-07 reg 5.000000e-01 train accuracy: 0.130714 val accuracy: 0.161000
lr 2.000000e-07 reg 1.000000e+00 train accuracy: 0.155041 val accuracy: 0.144000
lr 2.000000e-07 reg 5.000000e+03 train accuracy: 0.272918 val accuracy: 0.261000
lr 1.000000e-05 reg 1.000000e-02 train accuracy: 0.406796 val accuracy: 0.396000
lr 1.000000e-05 reg 1.000000e-01 train accuracy: 0.408510 val accuracy: 0.410000
lr 1.000000e-05 reg 2.000000e-01 train accuracy: 0.409163 val accuracy: 0.414000
lr 1.000000e-05 reg 5.000000e-01 train accuracy: 0.407816 val accuracy: 0.410000
lr 1.000000e-05 reg 1.000000e+00 train accuracy: 0.408490 val accuracy: 0.400000
lr 1.000000e-05 reg 5.000000e+03 train accuracy: 0.407367 val accuracy: 0.410000
lr 1.000000e-04 reg 1.000000e-02 train accuracy: 0.451776 val accuracy: 0.443000
lr 1.000000e-04 reg 1.000000e-01 train accuracy: 0.451367 val accuracy: 0.448000
```

```
lr 1.000000e-04 reg 2.000000e-01 train accuracy: 0.449531 val accuracy: 0.449000
lr 1.000000e-04 reg 5.000000e-01 train accuracy: 0.450388 val accuracy: 0.446000
lr 1.000000e-04 reg 1.000000e+00 train accuracy: 0.448592 val accuracy: 0.441000
lr 1.000000e-04 reg 5.000000e+03 train accuracy: 0.332102 val accuracy: 0.348000
lr 1.000000e-03 reg 1.000000e-02 train accuracy: 0.500061 val accuracy: 0.492000
lr 1.000000e-03 reg 1.000000e-01 train accuracy: 0.499041 val accuracy: 0.493000
lr 1.000000e-03 reg 2.000000e-01 train accuracy: 0.498041 val accuracy: 0.487000
lr 1.000000e-03 reg 5.000000e-01 train accuracy: 0.490449 val accuracy: 0.476000
lr 1.000000e-03 reg 1.000000e+00 train accuracy: 0.484878 val accuracy: 0.474000
lr 1.000000e-03 reg 5.000000e+03 train accuracy: 0.100265 val accuracy: 0.087000
best validation accuracy achieved during cross-validation: 0.493000
```

In [ ]:
```python
# Evaluate your trained SVM on the test set
y_test_pred = best_svm.predict(X_test_feats)
test_accuracy = np.mean(y_test == y_test_pred)
print(test_accuracy)
```
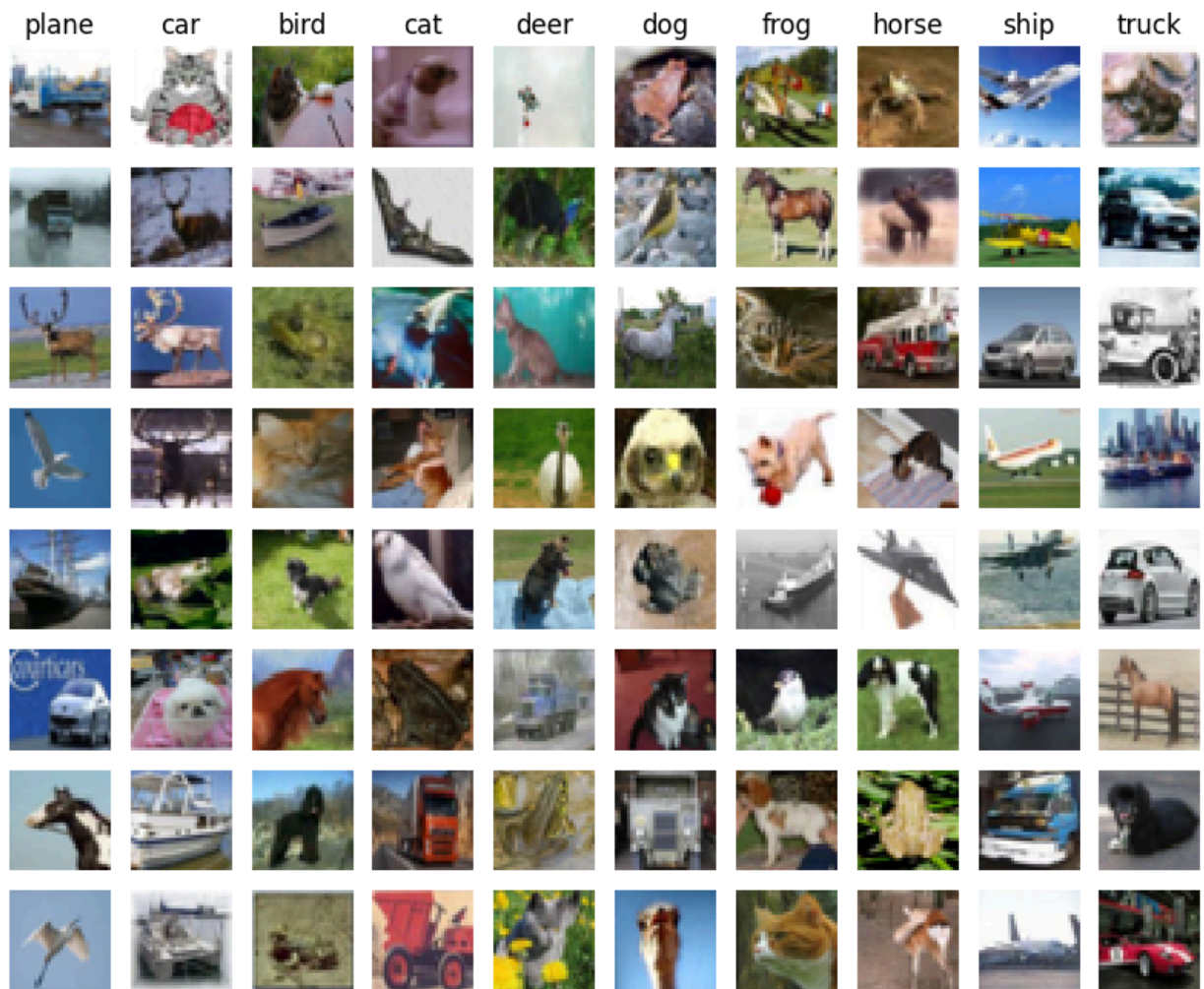
```
0.48
```

In [ ]:
```python
# 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', 'tru
for cls, cls_name in enumerate(classes):
    idxs = np.where((y_test != cls) & (y_test_pred == cls))[0]
    idxs = np.random.choice(idxs, examples_per_class, replace=False)
    for i, idx in enumerate(idxs):
        plt.subplot(examples_per_class, len(classes), i * len(classes) + cls + 1)
        plt.imshow(X_test[idx].astype('uint8'))
        plt.axis('off')
        if i == 0:
            plt.title(cls_name)
plt.show()
```

Inline question 1:

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

Yes, some of the misclassifications make sense:

1. Birds in flight are misclassified as planes, due the background colour of the image and the similarity in the images. Also images having significant blue background are misclassified as planes due to the similarity in the background colour.

2. Cat, deer, dog, frog and horse images are also misclassified due to common features like legs, eyes, shape of their body, similarities in fur textures, etc.

3. Vehicles like trucks and cars are also often misclassified due to similarity in their shapes and common features like wheels, etc.

4. Similar background images like ships and planes are also misclassified.

In conclusion, the combination of HOG and color histogram feature vectors is insufficient for achieving highly accurate classification between these classes. Improving feature extraction or dataset augmentation can further improve the systems accuracy.

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.

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

          print(X_train_feats.shape)
```

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

```
In [ ]:   from cs6353.classifiers.neural_net import TwoLayerNet

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

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

          ################################################################################
          # TODO: Train a two-layer neural network on image features. You may want to    #
          # cross-validate various parameters as in previous sections. Store your best   #
          # model in the best_net variable.                                             #
          ################################################################################
          learning_rates = [3e-1, 1e-2, 2e-3]
          regularization_strengths = [2e-7, 1e-7, 2e-5]
          hidden_layer_sizes = [100, 150, 175]
          num_of_epochs = [1500, 3000]
          results = {}
          best_val = -1

          for lr in learning_rates:
              for reg in regularization_strengths:
                  for hls in hidden_layer_sizes:
                      for epochs in num_of_epochs:

                          net = TwoLayerNet(input_dim, hls, num_classes)

                          stats = net.train(X_train_feats, y_train, X_val_feats, y_val,
                              num_iters=epochs, batch_size=200,
                              learning_rate=lr, learning_rate_decay=0.95,
                              reg=reg, verbose=True)
```

```python
            y_train_pred = net.predict(X_train_feats)
            y_val_pred = net.predict(X_val_feats)

            train_acc = np.mean(y_train_pred == y_train)
            val_acc = np.mean(y_val_pred == y_val)


            results[(lr, reg, hls, epochs)] = (train_acc, val_acc)
            print(lr, reg, hls, epochs, train_acc, val_acc)

            if val_acc > best_val:
                best_val = val_acc
                best_net = net
################################################################################
#                             END OF YOUR CODE                                 #
################################################################################
```

```
iteration 0 / 1500: loss 2.302585
iteration 100 / 1500: loss 1.837699
iteration 200 / 1500: loss 1.430180
iteration 300 / 1500: loss 1.461022
iteration 400 / 1500: loss 1.337830
iteration 500 / 1500: loss 1.316799
iteration 600 / 1500: loss 1.329158
iteration 700 / 1500: loss 1.259146
iteration 800 / 1500: loss 1.408602
iteration 900 / 1500: loss 1.379886
iteration 1000 / 1500: loss 1.123509
iteration 1100 / 1500: loss 1.109656
iteration 1200 / 1500: loss 1.054326
iteration 1300 / 1500: loss 1.163406
iteration 1400 / 1500: loss 1.215077
0.3 2e-07 100 1500 0.6139591836734694 0.572
iteration 0 / 3000: loss 2.302585
iteration 100 / 3000: loss 1.921849
iteration 200 / 3000: loss 1.503588
iteration 300 / 3000: loss 1.250968
iteration 400 / 3000: loss 1.316346
iteration 500 / 3000: loss 1.273989
iteration 600 / 3000: loss 1.394202
iteration 700 / 3000: loss 1.367919
iteration 800 / 3000: loss 1.254400
iteration 900 / 3000: loss 1.148793
iteration 1000 / 3000: loss 1.215016
iteration 1100 / 3000: loss 1.107165
iteration 1200 / 3000: loss 1.201162
iteration 1300 / 3000: loss 1.124361
iteration 1400 / 3000: loss 1.127846
iteration 1500 / 3000: loss 1.118782
iteration 1600 / 3000: loss 1.054724
iteration 1700 / 3000: loss 1.089153
iteration 1800 / 3000: loss 1.006425
iteration 1900 / 3000: loss 0.993421
iteration 2000 / 3000: loss 1.038893
iteration 2100 / 3000: loss 1.058492
iteration 2200 / 3000: loss 1.082460
iteration 2300 / 3000: loss 1.161133
iteration 2400 / 3000: loss 1.076711
iteration 2500 / 3000: loss 1.013445
iteration 2600 / 3000: loss 0.984464
iteration 2700 / 3000: loss 1.010282
iteration 2800 / 3000: loss 1.090771
iteration 2900 / 3000: loss 1.057545
0.3 2e-07 100 3000 0.6583061224489796 0.585
iteration 0 / 1500: loss 2.302585
iteration 100 / 1500: loss 1.825610
iteration 200 / 1500: loss 1.480830
iteration 300 / 1500: loss 1.360206
iteration 400 / 1500: loss 1.478022
iteration 500 / 1500: loss 1.315065
iteration 600 / 1500: loss 1.247591
iteration 700 / 1500: loss 1.234418
iteration 800 / 1500: loss 1.380980
iteration 900 / 1500: loss 1.182532
iteration 1000 / 1500: loss 1.106733
iteration 1100 / 1500: loss 1.216349
iteration 1200 / 1500: loss 1.142483
```

```
iteration 1300 / 1500: loss 1.217735
iteration 1400 / 1500: loss 1.201116
0.3 2e-07 150 1500 0.6227142857142857 0.571
iteration 0 / 3000: loss 2.302585
iteration 100 / 3000: loss 1.923236
iteration 200 / 3000: loss 1.405291
iteration 300 / 3000: loss 1.520795
iteration 400 / 3000: loss 1.328728
iteration 500 / 3000: loss 1.313827
iteration 600 / 3000: loss 1.339707
iteration 700 / 3000: loss 1.355101
iteration 800 / 3000: loss 1.221677
iteration 900 / 3000: loss 1.210339
iteration 1000 / 3000: loss 1.281490
iteration 1100 / 3000: loss 1.150248
iteration 1200 / 3000: loss 1.182286
iteration 1300 / 3000: loss 1.270046
iteration 1400 / 3000: loss 1.064207
iteration 1500 / 3000: loss 1.195812
iteration 1600 / 3000: loss 1.081500
iteration 1700 / 3000: loss 1.002393
iteration 1800 / 3000: loss 1.079138
iteration 1900 / 3000: loss 1.019485
iteration 2000 / 3000: loss 1.005818
iteration 2100 / 3000: loss 1.060225
iteration 2200 / 3000: loss 1.071140
iteration 2300 / 3000: loss 1.012516
iteration 2400 / 3000: loss 1.021231
iteration 2500 / 3000: loss 0.827208
iteration 2600 / 3000: loss 0.889679
iteration 2700 / 3000: loss 0.937680
iteration 2800 / 3000: loss 0.904265
iteration 2900 / 3000: loss 0.817346
0.3 2e-07 150 3000 0.6850612244897959 0.579
iteration 0 / 1500: loss 2.302585
iteration 100 / 1500: loss 1.857560
iteration 200 / 1500: loss 1.572749
iteration 300 / 1500: loss 1.267005
iteration 400 / 1500: loss 1.354619
iteration 500 / 1500: loss 1.258958
iteration 600 / 1500: loss 1.166776
iteration 700 / 1500: loss 1.230874
iteration 800 / 1500: loss 1.238824
iteration 900 / 1500: loss 1.201996
iteration 1000 / 1500: loss 1.145441
iteration 1100 / 1500: loss 1.084606
iteration 1200 / 1500: loss 1.008969
iteration 1300 / 1500: loss 0.981302
iteration 1400 / 1500: loss 0.996228
0.3 2e-07 175 1500 0.6257959183673469 0.574
iteration 0 / 3000: loss 2.302585
iteration 100 / 3000: loss 1.903254
iteration 200 / 3000: loss 1.487875
iteration 300 / 3000: loss 1.355269
iteration 400 / 3000: loss 1.339793
iteration 500 / 3000: loss 1.281435
iteration 600 / 3000: loss 1.255357
iteration 700 / 3000: loss 1.129785
iteration 800 / 3000: loss 1.081565
iteration 900 / 3000: loss 1.254100
```

```
iteration 1000 / 3000: loss 1.138822
iteration 1100 / 3000: loss 1.263180
iteration 1200 / 3000: loss 1.079415
iteration 1300 / 3000: loss 0.975581
iteration 1400 / 3000: loss 0.958881
iteration 1500 / 3000: loss 1.028240
iteration 1600 / 3000: loss 1.039519
iteration 1700 / 3000: loss 1.084825
iteration 1800 / 3000: loss 1.106511
iteration 1900 / 3000: loss 0.983309
iteration 2000 / 3000: loss 1.020936
iteration 2100 / 3000: loss 0.952577
iteration 2200 / 3000: loss 0.955561
iteration 2300 / 3000: loss 1.010738
iteration 2400 / 3000: loss 0.891842
iteration 2500 / 3000: loss 0.871702
iteration 2600 / 3000: loss 0.999913
iteration 2700 / 3000: loss 0.888187
iteration 2800 / 3000: loss 1.022731
iteration 2900 / 3000: loss 0.960904
0.3 2e-07 175 3000 0.6928775510204082 0.59
iteration 0 / 1500: loss 2.302585
iteration 100 / 1500: loss 1.914205
iteration 200 / 1500: loss 1.488031
iteration 300 / 1500: loss 1.446658
iteration 400 / 1500: loss 1.182026
iteration 500 / 1500: loss 1.261541
iteration 600 / 1500: loss 1.325419
iteration 700 / 1500: loss 1.345249
iteration 800 / 1500: loss 1.226613
iteration 900 / 1500: loss 1.193734
iteration 1000 / 1500: loss 1.296815
iteration 1100 / 1500: loss 1.259790
iteration 1200 / 1500: loss 1.192646
iteration 1300 / 1500: loss 1.051605
iteration 1400 / 1500: loss 1.090569
0.3 1e-07 100 1500 0.6111836734693877 0.551
iteration 0 / 3000: loss 2.302585
iteration 100 / 3000: loss 1.861578
iteration 200 / 3000: loss 1.420475
iteration 300 / 3000: loss 1.437324
iteration 400 / 3000: loss 1.407257
iteration 500 / 3000: loss 1.301119
iteration 600 / 3000: loss 1.259529
iteration 700 / 3000: loss 1.143872
iteration 800 / 3000: loss 1.079263
iteration 900 / 3000: loss 1.073315
iteration 1000 / 3000: loss 1.274614
iteration 1100 / 3000: loss 1.184006
iteration 1200 / 3000: loss 1.109554
iteration 1300 / 3000: loss 1.022257
iteration 1400 / 3000: loss 1.019454
iteration 1500 / 3000: loss 1.184491
iteration 1600 / 3000: loss 1.130063
iteration 1700 / 3000: loss 1.090259
iteration 1800 / 3000: loss 1.064923
iteration 1900 / 3000: loss 0.993765
iteration 2000 / 3000: loss 1.027432
iteration 2100 / 3000: loss 1.057841
iteration 2200 / 3000: loss 0.985762
```

```
               iteration 2300 / 3000: loss 1.074963
               iteration 2400 / 3000: loss 1.102784
               iteration 2500 / 3000: loss 0.983353
               iteration 2600 / 3000: loss 1.088187
               iteration 2700 / 3000: loss 1.023639
               iteration 2800 / 3000: loss 1.041927
               iteration 2900 / 3000: loss 0.879632
               0.3 1e-07 100 3000 0.6611836734693878 0.555
               iteration 0 / 1500: loss 2.302585
               iteration 100 / 1500: loss 1.824135
               iteration 200 / 1500: loss 1.436204
               iteration 300 / 1500: loss 1.453721
               iteration 400 / 1500: loss 1.473710
               iteration 500 / 1500: loss 1.478476
               iteration 600 / 1500: loss 1.361429
               iteration 700 / 1500: loss 1.214201
               iteration 800 / 1500: loss 1.207533
               iteration 900 / 1500: loss 1.217915
               iteration 1000 / 1500: loss 1.131833
               iteration 1100 / 1500: loss 1.011908
               iteration 1200 / 1500: loss 1.211687
               iteration 1300 / 1500: loss 1.083478
               iteration 1400 / 1500: loss 0.963578
               0.3 1e-07 150 1500 0.6167142857142857 0.576
               iteration 0 / 3000: loss 2.302585
               iteration 100 / 3000: loss 1.818691
               iteration 200 / 3000: loss 1.654387
               iteration 300 / 3000: loss 1.352701
               iteration 400 / 3000: loss 1.372019
               iteration 500 / 3000: loss 1.215856
               iteration 600 / 3000: loss 1.320398
               iteration 700 / 3000: loss 1.231753
               iteration 800 / 3000: loss 1.305710
               iteration 900 / 3000: loss 1.152225
               iteration 1000 / 3000: loss 1.164774
               iteration 1100 / 3000: loss 1.239725
               iteration 1200 / 3000: loss 1.180680
               iteration 1300 / 3000: loss 1.172873
               iteration 1400 / 3000: loss 1.103864
               iteration 1500 / 3000: loss 1.139673
               iteration 1600 / 3000: loss 0.949171
               iteration 1700 / 3000: loss 0.955011
               iteration 1800 / 3000: loss 0.911333
               iteration 1900 / 3000: loss 1.116908
               iteration 2000 / 3000: loss 1.103250
               iteration 2100 / 3000: loss 1.018802
               iteration 2200 / 3000: loss 1.064770
               iteration 2300 / 3000: loss 0.968589
               iteration 2400 / 3000: loss 0.928128
               iteration 2500 / 3000: loss 0.990355
               iteration 2600 / 3000: loss 0.987239
               iteration 2700 / 3000: loss 1.062059
               iteration 2800 / 3000: loss 0.981290
               iteration 2900 / 3000: loss 0.892102
               0.3 1e-07 150 3000 0.6801428571428572 0.575
               iteration 0 / 1500: loss 2.302585
               iteration 100 / 1500: loss 1.915168
               iteration 200 / 1500: loss 1.406389
               iteration 300 / 1500: loss 1.233515
               iteration 400 / 1500: loss 1.301279
```

```
iteration 500 / 1500: loss 1.224305
iteration 600 / 1500: loss 1.292745
iteration 700 / 1500: loss 1.171320
iteration 800 / 1500: loss 1.213119
iteration 900 / 1500: loss 1.230728
iteration 1000 / 1500: loss 1.097455
iteration 1100 / 1500: loss 1.161020
iteration 1200 / 1500: loss 1.148332
iteration 1300 / 1500: loss 1.108262
iteration 1400 / 1500: loss 1.103696
0.3 1e-07 175 1500 0.6268367346938776 0.563
iteration 0 / 3000: loss 2.302585
iteration 100 / 3000: loss 1.897716
iteration 200 / 3000: loss 1.552027
iteration 300 / 3000: loss 1.390646
iteration 400 / 3000: loss 1.308007
iteration 500 / 3000: loss 1.230168
iteration 600 / 3000: loss 1.279816
iteration 700 / 3000: loss 1.308391
iteration 800 / 3000: loss 1.173698
iteration 900 / 3000: loss 1.273260
iteration 1000 / 3000: loss 1.165451
iteration 1100 / 3000: loss 1.155267
iteration 1200 / 3000: loss 1.070129
iteration 1300 / 3000: loss 1.145944
iteration 1400 / 3000: loss 1.140940
iteration 1500 / 3000: loss 1.183665
iteration 1600 / 3000: loss 1.100796
iteration 1700 / 3000: loss 1.092760
iteration 1800 / 3000: loss 1.149449
iteration 1900 / 3000: loss 0.951859
iteration 2000 / 3000: loss 1.006551
iteration 2100 / 3000: loss 0.835124
iteration 2200 / 3000: loss 0.898580
iteration 2300 / 3000: loss 0.891952
iteration 2400 / 3000: loss 0.998279
iteration 2500 / 3000: loss 1.117451
iteration 2600 / 3000: loss 1.095574
iteration 2700 / 3000: loss 1.011762
iteration 2800 / 3000: loss 0.947734
iteration 2900 / 3000: loss 0.993534
0.3 1e-07 175 3000 0.6863061224489796 0.592
iteration 0 / 1500: loss 2.302585
iteration 100 / 1500: loss 1.889219
iteration 200 / 1500: loss 1.449334
iteration 300 / 1500: loss 1.459348
iteration 400 / 1500: loss 1.374681
iteration 500 / 1500: loss 1.313737
iteration 600 / 1500: loss 1.326432
iteration 700 / 1500: loss 1.382270
iteration 800 / 1500: loss 1.173156
iteration 900 / 1500: loss 1.208045
iteration 1000 / 1500: loss 1.107190
iteration 1100 / 1500: loss 1.263532
iteration 1200 / 1500: loss 1.164127
iteration 1300 / 1500: loss 1.183337
iteration 1400 / 1500: loss 1.077219
0.3 2e-05 100 1500 0.6079591836734693 0.564
iteration 0 / 3000: loss 2.302585
iteration 100 / 3000: loss 1.897828
```

```
iteration 200 / 3000: loss 1.467057
iteration 300 / 3000: loss 1.395959
iteration 400 / 3000: loss 1.392540
iteration 500 / 3000: loss 1.331435
iteration 600 / 3000: loss 1.271580
iteration 700 / 3000: loss 1.266743
iteration 800 / 3000: loss 1.250985
iteration 900 / 3000: loss 1.280351
iteration 1000 / 3000: loss 1.102922
iteration 1100 / 3000: loss 1.242154
iteration 1200 / 3000: loss 1.358491
iteration 1300 / 3000: loss 1.182420
iteration 1400 / 3000: loss 1.256858
iteration 1500 / 3000: loss 1.223502
iteration 1600 / 3000: loss 1.174015
iteration 1700 / 3000: loss 1.073848
iteration 1800 / 3000: loss 0.985025
iteration 1900 / 3000: loss 1.109320
iteration 2000 / 3000: loss 1.040313
iteration 2100 / 3000: loss 1.035139
iteration 2200 / 3000: loss 1.063179
iteration 2300 / 3000: loss 1.059575
iteration 2400 / 3000: loss 0.957594
iteration 2500 / 3000: loss 0.968469
iteration 2600 / 3000: loss 1.080336
iteration 2700 / 3000: loss 0.986587
iteration 2800 / 3000: loss 0.865402
iteration 2900 / 3000: loss 1.099529
0.3 2e-05 100 3000 0.6579183673469388 0.579
iteration 0 / 1500: loss 2.302585
iteration 100 / 1500: loss 1.876340
iteration 200 / 1500: loss 1.464171
iteration 300 / 1500: loss 1.304314
iteration 400 / 1500: loss 1.284944
iteration 500 / 1500: loss 1.276695
iteration 600 / 1500: loss 1.275961
iteration 700 / 1500: loss 1.214174
iteration 800 / 1500: loss 1.171265
iteration 900 / 1500: loss 1.305379
iteration 1000 / 1500: loss 1.229707
iteration 1100 / 1500: loss 1.146509
iteration 1200 / 1500: loss 1.152636
iteration 1300 / 1500: loss 1.087768
iteration 1400 / 1500: loss 1.136095
0.3 2e-05 150 1500 0.6160612244897959 0.563
iteration 0 / 3000: loss 2.302585
iteration 100 / 3000: loss 1.938511
iteration 200 / 3000: loss 1.428322
iteration 300 / 3000: loss 1.374366
iteration 400 / 3000: loss 1.402192
iteration 500 / 3000: loss 1.363606
iteration 600 / 3000: loss 1.398350
iteration 700 / 3000: loss 1.223098
iteration 800 / 3000: loss 1.147972
iteration 900 / 3000: loss 1.238309
iteration 1000 / 3000: loss 1.203515
iteration 1100 / 3000: loss 1.074834
iteration 1200 / 3000: loss 1.097596
iteration 1300 / 3000: loss 0.994037
iteration 1400 / 3000: loss 1.036411
```

```
iteration 1500 / 3000: loss 1.029644
iteration 1600 / 3000: loss 1.094589
iteration 1700 / 3000: loss 0.905588
iteration 1800 / 3000: loss 1.019745
iteration 1900 / 3000: loss 1.042735
iteration 2000 / 3000: loss 0.979338
iteration 2100 / 3000: loss 1.006893
iteration 2200 / 3000: loss 0.931205
iteration 2300 / 3000: loss 0.968058
iteration 2400 / 3000: loss 0.828188
iteration 2500 / 3000: loss 1.026215
iteration 2600 / 3000: loss 1.086503
iteration 2700 / 3000: loss 0.896616
iteration 2800 / 3000: loss 0.878320
iteration 2900 / 3000: loss 0.985768
0.3 2e-05 150 3000 0.6832857142857143 0.586
iteration 0 / 1500: loss 2.302585
iteration 100 / 1500: loss 1.900189
iteration 200 / 1500: loss 1.449862
iteration 300 / 1500: loss 1.386672
iteration 400 / 1500: loss 1.458359
iteration 500 / 1500: loss 1.313744
iteration 600 / 1500: loss 1.167334
iteration 700 / 1500: loss 1.186287
iteration 800 / 1500: loss 1.261683
iteration 900 / 1500: loss 1.260529
iteration 1000 / 1500: loss 1.179343
iteration 1100 / 1500: loss 1.073347
iteration 1200 / 1500: loss 1.040158
iteration 1300 / 1500: loss 1.123835
iteration 1400 / 1500: loss 1.153764
0.3 2e-05 175 1500 0.6233673469387755 0.577
iteration 0 / 3000: loss 2.302585
iteration 100 / 3000: loss 1.882834
iteration 200 / 3000: loss 1.345935
iteration 300 / 3000: loss 1.401120
iteration 400 / 3000: loss 1.217637
iteration 500 / 3000: loss 1.287546
iteration 600 / 3000: loss 1.267964
iteration 700 / 3000: loss 1.278788
iteration 800 / 3000: loss 1.187089
iteration 900 / 3000: loss 1.150295
iteration 1000 / 3000: loss 1.190415
iteration 1100 / 3000: loss 1.195944
iteration 1200 / 3000: loss 1.141844
iteration 1300 / 3000: loss 1.230643
iteration 1400 / 3000: loss 1.221038
iteration 1500 / 3000: loss 1.012293
iteration 1600 / 3000: loss 1.025338
iteration 1700 / 3000: loss 1.021385
iteration 1800 / 3000: loss 1.018242
iteration 1900 / 3000: loss 1.017006
iteration 2000 / 3000: loss 0.932952
iteration 2100 / 3000: loss 0.870121
iteration 2200 / 3000: loss 0.975799
iteration 2300 / 3000: loss 0.957460
iteration 2400 / 3000: loss 0.922303
iteration 2500 / 3000: loss 0.926949
iteration 2600 / 3000: loss 0.798439
iteration 2700 / 3000: loss 1.029576
```

```
iteration 2800 / 3000: loss 0.922554
iteration 2900 / 3000: loss 0.905369
0.3 2e-05 175 3000 0.6830204081632653 0.58
iteration 0 / 1500: loss 2.302585
iteration 100 / 1500: loss 2.302368
iteration 200 / 1500: loss 2.302862
iteration 300 / 1500: loss 2.302603
iteration 400 / 1500: loss 2.302851
iteration 500 / 1500: loss 2.303004
iteration 600 / 1500: loss 2.303145
iteration 700 / 1500: loss 2.302993
iteration 800 / 1500: loss 2.302778
iteration 900 / 1500: loss 2.302412
iteration 1000 / 1500: loss 2.302888
iteration 1100 / 1500: loss 2.302488
iteration 1200 / 1500: loss 2.302207
iteration 1300 / 1500: loss 2.302131
iteration 1400 / 1500: loss 2.302267
0.01 2e-07 100 1500 0.10404081632653062 0.08
iteration 0 / 3000: loss 2.302585
iteration 100 / 3000: loss 2.302385
iteration 200 / 3000: loss 2.302665
iteration 300 / 3000: loss 2.302539
iteration 400 / 3000: loss 2.302594
iteration 500 / 3000: loss 2.302518
iteration 600 / 3000: loss 2.302699
iteration 700 / 3000: loss 2.302904
iteration 800 / 3000: loss 2.302663
iteration 900 / 3000: loss 2.302749
iteration 1000 / 3000: loss 2.303077
iteration 1100 / 3000: loss 2.303139
iteration 1200 / 3000: loss 2.302096
iteration 1300 / 3000: loss 2.303164
iteration 1400 / 3000: loss 2.302028
iteration 1500 / 3000: loss 2.302835
iteration 1600 / 3000: loss 2.301581
iteration 1700 / 3000: loss 2.301586
iteration 1800 / 3000: loss 2.299801
iteration 1900 / 3000: loss 2.297119
iteration 2000 / 3000: loss 2.295164
iteration 2100 / 3000: loss 2.291991
iteration 2200 / 3000: loss 2.285401
iteration 2300 / 3000: loss 2.274336
iteration 2400 / 3000: loss 2.263266
iteration 2500 / 3000: loss 2.258734
iteration 2600 / 3000: loss 2.220088
iteration 2700 / 3000: loss 2.160037
iteration 2800 / 3000: loss 2.162099
iteration 2900 / 3000: loss 2.169093
0.01 2e-07 100 3000 0.22542857142857142 0.229
iteration 0 / 1500: loss 2.302585
iteration 100 / 1500: loss 2.302540
iteration 200 / 1500: loss 2.302596
iteration 300 / 1500: loss 2.302595
iteration 400 / 1500: loss 2.302602
iteration 500 / 1500: loss 2.302839
iteration 600 / 1500: loss 2.302399
iteration 700 / 1500: loss 2.302638
iteration 800 / 1500: loss 2.302492
iteration 900 / 1500: loss 2.302391
```

```
iteration 1000 / 1500: loss 2.302188
iteration 1100 / 1500: loss 2.302269
iteration 1200 / 1500: loss 2.302604
iteration 1300 / 1500: loss 2.301440
iteration 1400 / 1500: loss 2.301645
0.01 2e-07 150 1500 0.09973469387755102 0.113
iteration 0 / 3000: loss 2.302585
iteration 100 / 3000: loss 2.302563
iteration 200 / 3000: loss 2.302631
iteration 300 / 3000: loss 2.302477
iteration 400 / 3000: loss 2.302772
iteration 500 / 3000: loss 2.302506
iteration 600 / 3000: loss 2.302655
iteration 700 / 3000: loss 2.302647
iteration 800 / 3000: loss 2.302432
iteration 900 / 3000: loss 2.302394
iteration 1000 / 3000: loss 2.302795
iteration 1100 / 3000: loss 2.302198
iteration 1200 / 3000: loss 2.302038
iteration 1300 / 3000: loss 2.302742
iteration 1400 / 3000: loss 2.301864
iteration 1500 / 3000: loss 2.301677
iteration 1600 / 3000: loss 2.299826
iteration 1700 / 3000: loss 2.298890
iteration 1800 / 3000: loss 2.296451
iteration 1900 / 3000: loss 2.293659
iteration 2000 / 3000: loss 2.286151
iteration 2100 / 3000: loss 2.274136
iteration 2200 / 3000: loss 2.267897
iteration 2300 / 3000: loss 2.258705
iteration 2400 / 3000: loss 2.234010
iteration 2500 / 3000: loss 2.219267
iteration 2600 / 3000: loss 2.222774
iteration 2700 / 3000: loss 2.162052
iteration 2800 / 3000: loss 2.145215
iteration 2900 / 3000: loss 2.097989
0.01 2e-07 150 3000 0.22053061224489795 0.227
iteration 0 / 1500: loss 2.302585
iteration 100 / 1500: loss 2.302712
iteration 200 / 1500: loss 2.302499
iteration 300 / 1500: loss 2.302624
iteration 400 / 1500: loss 2.302353
iteration 500 / 1500: loss 2.302877
iteration 600 / 1500: loss 2.302841
iteration 700 / 1500: loss 2.302409
iteration 800 / 1500: loss 2.302593
iteration 900 / 1500: loss 2.302764
iteration 1000 / 1500: loss 2.302312
iteration 1100 / 1500: loss 2.302225
iteration 1200 / 1500: loss 2.302077
iteration 1300 / 1500: loss 2.302521
iteration 1400 / 1500: loss 2.301736
0.01 2e-07 175 1500 0.16438775510204082 0.137
iteration 0 / 3000: loss 2.302585
iteration 100 / 3000: loss 2.302372
iteration 200 / 3000: loss 2.302878
iteration 300 / 3000: loss 2.302751
iteration 400 / 3000: loss 2.302939
iteration 500 / 3000: loss 2.302657
iteration 600 / 3000: loss 2.302907
```

```
iteration 700 / 3000: loss 2.302776
iteration 800 / 3000: loss 2.302607
iteration 900 / 3000: loss 2.301990
iteration 1000 / 3000: loss 2.302340
iteration 1100 / 3000: loss 2.302366
iteration 1200 / 3000: loss 2.302131
iteration 1300 / 3000: loss 2.302303
iteration 1400 / 3000: loss 2.301259
iteration 1500 / 3000: loss 2.301075
iteration 1600 / 3000: loss 2.300169
iteration 1700 / 3000: loss 2.297560
iteration 1800 / 3000: loss 2.292704
iteration 1900 / 3000: loss 2.289782
iteration 2000 / 3000: loss 2.282547
iteration 2100 / 3000: loss 2.278380
iteration 2200 / 3000: loss 2.263431
iteration 2300 / 3000: loss 2.228548
iteration 2400 / 3000: loss 2.226201
iteration 2500 / 3000: loss 2.171598
iteration 2600 / 3000: loss 2.194760
iteration 2700 / 3000: loss 2.184700
iteration 2800 / 3000: loss 2.101624
iteration 2900 / 3000: loss 2.104112
0.01 2e-07 175 3000 0.22610204081632654 0.238
iteration 0 / 1500: loss 2.302585
iteration 100 / 1500: loss 2.302644
iteration 200 / 1500: loss 2.302478
iteration 300 / 1500: loss 2.302388
iteration 400 / 1500: loss 2.302529
iteration 500 / 1500: loss 2.302468
iteration 600 / 1500: loss 2.302544
iteration 700 / 1500: loss 2.302569
iteration 800 / 1500: loss 2.302753
iteration 900 / 1500: loss 2.302768
iteration 1000 / 1500: loss 2.302321
iteration 1100 / 1500: loss 2.302215
iteration 1200 / 1500: loss 2.302138
iteration 1300 / 1500: loss 2.301607
iteration 1400 / 1500: loss 2.301439
0.01 1e-07 100 1500 0.1070204081632653 0.102
iteration 0 / 3000: loss 2.302585
iteration 100 / 3000: loss 2.302703
iteration 200 / 3000: loss 2.302399
iteration 300 / 3000: loss 2.302826
iteration 400 / 3000: loss 2.302619
iteration 500 / 3000: loss 2.302652
iteration 600 / 3000: loss 2.302965
iteration 700 / 3000: loss 2.302807
iteration 800 / 3000: loss 2.302518
iteration 900 / 3000: loss 2.302443
iteration 1000 / 3000: loss 2.302669
iteration 1100 / 3000: loss 2.302155
iteration 1200 / 3000: loss 2.302319
iteration 1300 / 3000: loss 2.302065
iteration 1400 / 3000: loss 2.302032
iteration 1500 / 3000: loss 2.301116
iteration 1600 / 3000: loss 2.300535
iteration 1700 / 3000: loss 2.300073
iteration 1800 / 3000: loss 2.297418
iteration 1900 / 3000: loss 2.293003
```

```
                    iteration 2000 / 3000: loss 2.294170
                    iteration 2100 / 3000: loss 2.281406
                    iteration 2200 / 3000: loss 2.270719
                    iteration 2300 / 3000: loss 2.257893
                    iteration 2400 / 3000: loss 2.237729
                    iteration 2500 / 3000: loss 2.194151
                    iteration 2600 / 3000: loss 2.200797
                    iteration 2700 / 3000: loss 2.188218
                    iteration 2800 / 3000: loss 2.194815
                    iteration 2900 / 3000: loss 2.120827
                    0.01 1e-07 100 3000 0.23751020408163265 0.24
                    iteration 0 / 1500: loss 2.302585
                    iteration 100 / 1500: loss 2.302671
                    iteration 200 / 1500: loss 2.302384
                    iteration 300 / 1500: loss 2.302482
                    iteration 400 / 1500: loss 2.301626
                    iteration 500 / 1500: loss 2.302649
                    iteration 600 / 1500: loss 2.302525
                    iteration 700 / 1500: loss 2.302765
                    iteration 800 / 1500: loss 2.302801
                    iteration 900 / 1500: loss 2.302926
                    iteration 1000 / 1500: loss 2.302169
                    iteration 1100 / 1500: loss 2.302026
                    iteration 1200 / 1500: loss 2.302011
                    iteration 1300 / 1500: loss 2.302523
                    iteration 1400 / 1500: loss 2.301994
                    0.01 1e-07 150 1500 0.1466938775510204 0.136
                    iteration 0 / 3000: loss 2.302585
                    iteration 100 / 3000: loss 2.302607
                    iteration 200 / 3000: loss 2.302527
                    iteration 300 / 3000: loss 2.302969
                    iteration 400 / 3000: loss 2.302510
                    iteration 500 / 3000: loss 2.302596
                    iteration 600 / 3000: loss 2.302503
                    iteration 700 / 3000: loss 2.302206
                    iteration 800 / 3000: loss 2.302721
                    iteration 900 / 3000: loss 2.302597
                    iteration 1000 / 3000: loss 2.302324
                    iteration 1100 / 3000: loss 2.302197
                    iteration 1200 / 3000: loss 2.302448
                    iteration 1300 / 3000: loss 2.302359
                    iteration 1400 / 3000: loss 2.301896
                    iteration 1500 / 3000: loss 2.300958
                    iteration 1600 / 3000: loss 2.300187
                    iteration 1700 / 3000: loss 2.300165
                    iteration 1800 / 3000: loss 2.298185
                    iteration 1900 / 3000: loss 2.291383
                    iteration 2000 / 3000: loss 2.284457
                    iteration 2100 / 3000: loss 2.273926
                    iteration 2200 / 3000: loss 2.266884
                    iteration 2300 / 3000: loss 2.250609
                    iteration 2400 / 3000: loss 2.228279
                    iteration 2500 / 3000: loss 2.204118
                    iteration 2600 / 3000: loss 2.212226
                    iteration 2700 / 3000: loss 2.154979
                    iteration 2800 / 3000: loss 2.122800
                    iteration 2900 / 3000: loss 2.097730
                    0.01 1e-07 150 3000 0.22844897959183674 0.237
                    iteration 0 / 1500: loss 2.302585
                    iteration 100 / 1500: loss 2.302739
```

```
iteration 200 / 1500: loss 2.302319
iteration 300 / 1500: loss 2.302449
iteration 400 / 1500: loss 2.302542
iteration 500 / 1500: loss 2.302447
iteration 600 / 1500: loss 2.302920
iteration 700 / 1500: loss 2.302200
iteration 800 / 1500: loss 2.302850
iteration 900 / 1500: loss 2.302698
iteration 1000 / 1500: loss 2.302572
iteration 1100 / 1500: loss 2.302235
iteration 1200 / 1500: loss 2.301657
iteration 1300 / 1500: loss 2.301871
iteration 1400 / 1500: loss 2.301647
0.01 1e-07 175 1500 0.15210204081632653 0.123
iteration 0 / 3000: loss 2.302585
iteration 100 / 3000: loss 2.302565
iteration 200 / 3000: loss 2.302949
iteration 300 / 3000: loss 2.302270
iteration 400 / 3000: loss 2.302519
iteration 500 / 3000: loss 2.301678
iteration 600 / 3000: loss 2.302605
iteration 700 / 3000: loss 2.302892
iteration 800 / 3000: loss 2.303030
iteration 900 / 3000: loss 2.302206
iteration 1000 / 3000: loss 2.302667
iteration 1100 / 3000: loss 2.302402
iteration 1200 / 3000: loss 2.301703
iteration 1300 / 3000: loss 2.301596
iteration 1400 / 3000: loss 2.301610
iteration 1500 / 3000: loss 2.301427
iteration 1600 / 3000: loss 2.299857
iteration 1700 / 3000: loss 2.297366
iteration 1800 / 3000: loss 2.294597
iteration 1900 / 3000: loss 2.286632
iteration 2000 / 3000: loss 2.283065
iteration 2100 / 3000: loss 2.261999
iteration 2200 / 3000: loss 2.252287
iteration 2300 / 3000: loss 2.219027
iteration 2400 / 3000: loss 2.229507
iteration 2500 / 3000: loss 2.223188
iteration 2600 / 3000: loss 2.199199
iteration 2700 / 3000: loss 2.159499
iteration 2800 / 3000: loss 2.123331
iteration 2900 / 3000: loss 2.099282
0.01 1e-07 175 3000 0.22853061224489796 0.238
iteration 0 / 1500: loss 2.302585
iteration 100 / 1500: loss 2.302442
iteration 200 / 1500: loss 2.302642
iteration 300 / 1500: loss 2.302479
iteration 400 / 1500: loss 2.302237
iteration 500 / 1500: loss 2.302822
iteration 600 / 1500: loss 2.302235
iteration 700 / 1500: loss 2.302426
iteration 800 / 1500: loss 2.302163
iteration 900 / 1500: loss 2.302943
iteration 1000 / 1500: loss 2.302986
iteration 1100 / 1500: loss 2.302309
iteration 1200 / 1500: loss 2.302039
iteration 1300 / 1500: loss 2.302187
iteration 1400 / 1500: loss 2.301045
```

```
0.01 2e-05 100 1500 0.14420408163265305 0.114
iteration 0 / 3000: loss 2.302585
iteration 100 / 3000: loss 2.302538
iteration 200 / 3000: loss 2.302608
iteration 300 / 3000: loss 2.302563
iteration 400 / 3000: loss 2.302659
iteration 500 / 3000: loss 2.302384
iteration 600 / 3000: loss 2.302592
iteration 700 / 3000: loss 2.302677
iteration 800 / 3000: loss 2.302580
iteration 900 / 3000: loss 2.302607
iteration 1000 / 3000: loss 2.302196
iteration 1100 / 3000: loss 2.302608
iteration 1200 / 3000: loss 2.302411
iteration 1300 / 3000: loss 2.302046
iteration 1400 / 3000: loss 2.301888
iteration 1500 / 3000: loss 2.301288
iteration 1600 / 3000: loss 2.300899
iteration 1700 / 3000: loss 2.299483
iteration 1800 / 3000: loss 2.298019
iteration 1900 / 3000: loss 2.294437
iteration 2000 / 3000: loss 2.288907
iteration 2100 / 3000: loss 2.282757
iteration 2200 / 3000: loss 2.274444
iteration 2300 / 3000: loss 2.255691
iteration 2400 / 3000: loss 2.226529
iteration 2500 / 3000: loss 2.216729
iteration 2600 / 3000: loss 2.219719
iteration 2700 / 3000: loss 2.173546
iteration 2800 / 3000: loss 2.129247
iteration 2900 / 3000: loss 2.164320
0.01 2e-05 100 3000 0.2257142857142857 0.231
iteration 0 / 1500: loss 2.302585
iteration 100 / 1500: loss 2.302590
iteration 200 / 1500: loss 2.302669
iteration 300 / 1500: loss 2.302881
iteration 400 / 1500: loss 2.302754
iteration 500 / 1500: loss 2.302584
iteration 600 / 1500: loss 2.302606
iteration 700 / 1500: loss 2.302535
iteration 800 / 1500: loss 2.302563
iteration 900 / 1500: loss 2.302261
iteration 1000 / 1500: loss 2.302769
iteration 1100 / 1500: loss 2.302256
iteration 1200 / 1500: loss 2.302271
iteration 1300 / 1500: loss 2.302136
iteration 1400 / 1500: loss 2.301716
0.01 2e-05 150 1500 0.18193877551020407 0.201
iteration 0 / 3000: loss 2.302585
iteration 100 / 3000: loss 2.302464
iteration 200 / 3000: loss 2.302680
iteration 300 / 3000: loss 2.302705
iteration 400 / 3000: loss 2.302140
iteration 500 / 3000: loss 2.302290
iteration 600 / 3000: loss 2.302594
iteration 700 / 3000: loss 2.302060
iteration 800 / 3000: loss 2.302608
iteration 900 / 3000: loss 2.301997
iteration 1000 / 3000: loss 2.301984
iteration 1100 / 3000: loss 2.302805
```

```
iteration 1200 / 3000: loss 2.302528
iteration 1300 / 3000: loss 2.301978
iteration 1400 / 3000: loss 2.301621
iteration 1500 / 3000: loss 2.301262
iteration 1600 / 3000: loss 2.299780
iteration 1700 / 3000: loss 2.298482
iteration 1800 / 3000: loss 2.297186
iteration 1900 / 3000: loss 2.291540
iteration 2000 / 3000: loss 2.286660
iteration 2100 / 3000: loss 2.276794
iteration 2200 / 3000: loss 2.274018
iteration 2300 / 3000: loss 2.236958
iteration 2400 / 3000: loss 2.219090
iteration 2500 / 3000: loss 2.187036
iteration 2600 / 3000: loss 2.197137
iteration 2700 / 3000: loss 2.159185
iteration 2800 / 3000: loss 2.123648
iteration 2900 / 3000: loss 2.154456
0.01 2e-05 150 3000 0.22646938775510203 0.236
iteration 0 / 1500: loss 2.302585
iteration 100 / 1500: loss 2.302417
iteration 200 / 1500: loss 2.302522
iteration 300 / 1500: loss 2.302280
iteration 400 / 1500: loss 2.302275
iteration 500 / 1500: loss 2.303152
iteration 600 / 1500: loss 2.302241
iteration 700 / 1500: loss 2.302172
iteration 800 / 1500: loss 2.302780
iteration 900 / 1500: loss 2.302562
iteration 1000 / 1500: loss 2.302184
iteration 1100 / 1500: loss 2.302570
iteration 1200 / 1500: loss 2.302123
iteration 1300 / 1500: loss 2.301957
iteration 1400 / 1500: loss 2.301381
0.01 2e-05 175 1500 0.10026530612244898 0.087
iteration 0 / 3000: loss 2.302585
iteration 100 / 3000: loss 2.302693
iteration 200 / 3000: loss 2.302444
iteration 300 / 3000: loss 2.302715
iteration 400 / 3000: loss 2.302563
iteration 500 / 3000: loss 2.302223
iteration 600 / 3000: loss 2.302527
iteration 700 / 3000: loss 2.302216
iteration 800 / 3000: loss 2.302796
iteration 900 / 3000: loss 2.301881
iteration 1000 / 3000: loss 2.302430
iteration 1100 / 3000: loss 2.302662
iteration 1200 / 3000: loss 2.302348
iteration 1300 / 3000: loss 2.302231
iteration 1400 / 3000: loss 2.301804
iteration 1500 / 3000: loss 2.301310
iteration 1600 / 3000: loss 2.300744
iteration 1700 / 3000: loss 2.298646
iteration 1800 / 3000: loss 2.295363
iteration 1900 / 3000: loss 2.292592
iteration 2000 / 3000: loss 2.285332
iteration 2100 / 3000: loss 2.278908
iteration 2200 / 3000: loss 2.266085
iteration 2300 / 3000: loss 2.260659
iteration 2400 / 3000: loss 2.252183
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iteration 2500 / 3000: loss 2.214742
iteration 2600 / 3000: loss 2.145333
iteration 2700 / 3000: loss 2.179101
iteration 2800 / 3000: loss 2.140991
iteration 2900 / 3000: loss 2.153157
0.01 2e-05 175 3000 0.23173469387755102 0.255
iteration 0 / 1500: loss 2.302585
iteration 100 / 1500: loss 2.302598
iteration 200 / 1500: loss 2.302633
iteration 300 / 1500: loss 2.302686
iteration 400 / 1500: loss 2.302631
iteration 500 / 1500: loss 2.302598
iteration 600 / 1500: loss 2.302514
iteration 700 / 1500: loss 2.302789
iteration 800 / 1500: loss 2.302664
iteration 900 / 1500: loss 2.302579
iteration 1000 / 1500: loss 2.302507
iteration 1100 / 1500: loss 2.302752
iteration 1200 / 1500: loss 2.302552
iteration 1300 / 1500: loss 2.302490
iteration 1400 / 1500: loss 2.302505
0.002 2e-07 100 1500 0.09985714285714285 0.107
iteration 0 / 3000: loss 2.302585
iteration 100 / 3000: loss 2.302579
iteration 200 / 3000: loss 2.302575
iteration 300 / 3000: loss 2.302496
iteration 400 / 3000: loss 2.302408
iteration 500 / 3000: loss 2.302436
iteration 600 / 3000: loss 2.302518
iteration 700 / 3000: loss 2.302472
iteration 800 / 3000: loss 2.302752
iteration 900 / 3000: loss 2.302604
iteration 1000 / 3000: loss 2.302600
iteration 1100 / 3000: loss 2.302580
iteration 1200 / 3000: loss 2.302732
iteration 1300 / 3000: loss 2.302572
iteration 1400 / 3000: loss 2.302624
iteration 1500 / 3000: loss 2.302704
iteration 1600 / 3000: loss 2.302743
iteration 1700 / 3000: loss 2.302557
iteration 1800 / 3000: loss 2.302759
iteration 1900 / 3000: loss 2.302641
iteration 2000 / 3000: loss 2.302648
iteration 2100 / 3000: loss 2.302766
iteration 2200 / 3000: loss 2.302628
iteration 2300 / 3000: loss 2.302586
iteration 2400 / 3000: loss 2.302570
iteration 2500 / 3000: loss 2.302693
iteration 2600 / 3000: loss 2.302557
iteration 2700 / 3000: loss 2.302556
iteration 2800 / 3000: loss 2.302496
iteration 2900 / 3000: loss 2.302458
0.002 2e-07 100 3000 0.10004081632653061 0.098
iteration 0 / 1500: loss 2.302585
iteration 100 / 1500: loss 2.302588
iteration 200 / 1500: loss 2.302496
iteration 300 / 1500: loss 2.302537
iteration 400 / 1500: loss 2.302579
iteration 500 / 1500: loss 2.302557
iteration 600 / 1500: loss 2.302507
```

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iteration 700 / 1500: loss 2.302604
iteration 800 / 1500: loss 2.302646
iteration 900 / 1500: loss 2.302490
iteration 1000 / 1500: loss 2.302423
iteration 1100 / 1500: loss 2.302663
iteration 1200 / 1500: loss 2.302497
iteration 1300 / 1500: loss 2.302672
iteration 1400 / 1500: loss 2.302370
0.002 2e-07 150 1500 0.10044897959183674 0.078
iteration 0 / 3000: loss 2.302585
iteration 100 / 3000: loss 2.302579
iteration 200 / 3000: loss 2.302596
iteration 300 / 3000: loss 2.302467
iteration 400 / 3000: loss 2.302614
iteration 500 / 3000: loss 2.302534
iteration 600 / 3000: loss 2.302573
iteration 700 / 3000: loss 2.302641
iteration 800 / 3000: loss 2.302703
iteration 900 / 3000: loss 2.302621
iteration 1000 / 3000: loss 2.302544
iteration 1100 / 3000: loss 2.302563
iteration 1200 / 3000: loss 2.302517
iteration 1300 / 3000: loss 2.302529
iteration 1400 / 3000: loss 2.302607
iteration 1500 / 3000: loss 2.302554
iteration 1600 / 3000: loss 2.302661
iteration 1700 / 3000: loss 2.302581
iteration 1800 / 3000: loss 2.302563
iteration 1900 / 3000: loss 2.302562
iteration 2000 / 3000: loss 2.302551
iteration 2100 / 3000: loss 2.302514
iteration 2200 / 3000: loss 2.302467
iteration 2300 / 3000: loss 2.302622
iteration 2400 / 3000: loss 2.302478
iteration 2500 / 3000: loss 2.302706
iteration 2600 / 3000: loss 2.302542
iteration 2700 / 3000: loss 2.302449
iteration 2800 / 3000: loss 2.302618
iteration 2900 / 3000: loss 2.302611
0.002 2e-07 150 3000 0.10044897959183674 0.078
iteration 0 / 1500: loss 2.302585
iteration 100 / 1500: loss 2.302589
iteration 200 / 1500: loss 2.302597
iteration 300 / 1500: loss 2.302553
iteration 400 / 1500: loss 2.302659
iteration 500 / 1500: loss 2.302710
iteration 600 / 1500: loss 2.302721
iteration 700 / 1500: loss 2.302615
iteration 800 / 1500: loss 2.302544
iteration 900 / 1500: loss 2.302553
iteration 1000 / 1500: loss 2.302593
iteration 1100 / 1500: loss 2.302596
iteration 1200 / 1500: loss 2.302605
iteration 1300 / 1500: loss 2.302567
iteration 1400 / 1500: loss 2.302612
0.002 2e-07 175 1500 0.10004081632653061 0.098
iteration 0 / 3000: loss 2.302585
iteration 100 / 3000: loss 2.302597
iteration 200 / 3000: loss 2.302583
iteration 300 / 3000: loss 2.302671
```

```
iteration 400 / 3000: loss 2.302533
iteration 500 / 3000: loss 2.302603
iteration 600 / 3000: loss 2.302617
iteration 700 / 3000: loss 2.302582
iteration 800 / 3000: loss 2.302616
iteration 900 / 3000: loss 2.302623
iteration 1000 / 3000: loss 2.302487
iteration 1100 / 3000: loss 2.302506
iteration 1200 / 3000: loss 2.302589
iteration 1300 / 3000: loss 2.302561
iteration 1400 / 3000: loss 2.302524
iteration 1500 / 3000: loss 2.302663
iteration 1600 / 3000: loss 2.302599
iteration 1700 / 3000: loss 2.302477
iteration 1800 / 3000: loss 2.302498
iteration 1900 / 3000: loss 2.302489
iteration 2000 / 3000: loss 2.302415
iteration 2100 / 3000: loss 2.302623
iteration 2200 / 3000: loss 2.302620
iteration 2300 / 3000: loss 2.302544
iteration 2400 / 3000: loss 2.302818
iteration 2500 / 3000: loss 2.302699
iteration 2600 / 3000: loss 2.302597
iteration 2700 / 3000: loss 2.302661
iteration 2800 / 3000: loss 2.302787
iteration 2900 / 3000: loss 2.302555
0.002 2e-07 175 3000 0.10042857142857142 0.079
iteration 0 / 1500: loss 2.302585
iteration 100 / 1500: loss 2.302615
iteration 200 / 1500: loss 2.302602
iteration 300 / 1500: loss 2.302554
iteration 400 / 1500: loss 2.302594
iteration 500 / 1500: loss 2.302588
iteration 600 / 1500: loss 2.302597
iteration 700 / 1500: loss 2.302612
iteration 800 / 1500: loss 2.302725
iteration 900 / 1500: loss 2.302512
iteration 1000 / 1500: loss 2.302500
iteration 1100 / 1500: loss 2.302682
iteration 1200 / 1500: loss 2.302623
iteration 1300 / 1500: loss 2.302530
iteration 1400 / 1500: loss 2.302615
0.002 1e-07 100 1500 0.10026530612244898 0.087
iteration 0 / 3000: loss 2.302585
iteration 100 / 3000: loss 2.302594
iteration 200 / 3000: loss 2.302584
iteration 300 / 3000: loss 2.302602
iteration 400 / 3000: loss 2.302587
iteration 500 / 3000: loss 2.302636
iteration 600 / 3000: loss 2.302575
iteration 700 / 3000: loss 2.302645
iteration 800 / 3000: loss 2.302553
iteration 900 / 3000: loss 2.302697
iteration 1000 / 3000: loss 2.302674
iteration 1100 / 3000: loss 2.302590
iteration 1200 / 3000: loss 2.302633
iteration 1300 / 3000: loss 2.302619
iteration 1400 / 3000: loss 2.302499
iteration 1500 / 3000: loss 2.302598
iteration 1600 / 3000: loss 2.302629
```

```
iteration 1700 / 3000: loss 2.302622
iteration 1800 / 3000: loss 2.302624
iteration 1900 / 3000: loss 2.302539
iteration 2000 / 3000: loss 2.302532
iteration 2100 / 3000: loss 2.302595
iteration 2200 / 3000: loss 2.302503
iteration 2300 / 3000: loss 2.302622
iteration 2400 / 3000: loss 2.302468
iteration 2500 / 3000: loss 2.302413
iteration 2600 / 3000: loss 2.302551
iteration 2700 / 3000: loss 2.302616
iteration 2800 / 3000: loss 2.302598
iteration 2900 / 3000: loss 2.302543
0.002 1e-07 100 3000 0.10044897959183674 0.078
iteration 0 / 1500: loss 2.302585
iteration 100 / 1500: loss 2.302642
iteration 200 / 1500: loss 2.302588
iteration 300 / 1500: loss 2.302567
iteration 400 / 1500: loss 2.302566
iteration 500 / 1500: loss 2.302675
iteration 600 / 1500: loss 2.302394
iteration 700 / 1500: loss 2.302549
iteration 800 / 1500: loss 2.302631
iteration 900 / 1500: loss 2.302534
iteration 1000 / 1500: loss 2.302519
iteration 1100 / 1500: loss 2.302509
iteration 1200 / 1500: loss 2.302641
iteration 1300 / 1500: loss 2.302715
iteration 1400 / 1500: loss 2.302517
0.002 1e-07 150 1500 0.10042857142857142 0.079
iteration 0 / 3000: loss 2.302585
iteration 100 / 3000: loss 2.302533
iteration 200 / 3000: loss 2.302635
iteration 300 / 3000: loss 2.302541
iteration 400 / 3000: loss 2.302550
iteration 500 / 3000: loss 2.302608
iteration 600 / 3000: loss 2.302529
iteration 700 / 3000: loss 2.302490
iteration 800 / 3000: loss 2.302635
iteration 900 / 3000: loss 2.302563
iteration 1000 / 3000: loss 2.302611
iteration 1100 / 3000: loss 2.302656
iteration 1200 / 3000: loss 2.302471
iteration 1300 / 3000: loss 2.302592
iteration 1400 / 3000: loss 2.302592
iteration 1500 / 3000: loss 2.302543
iteration 1600 / 3000: loss 2.302757
iteration 1700 / 3000: loss 2.302626
iteration 1800 / 3000: loss 2.302368
iteration 1900 / 3000: loss 2.302462
iteration 2000 / 3000: loss 2.302676
iteration 2100 / 3000: loss 2.302615
iteration 2200 / 3000: loss 2.302693
iteration 2300 / 3000: loss 2.302603
iteration 2400 / 3000: loss 2.302740
iteration 2500 / 3000: loss 2.302679
iteration 2600 / 3000: loss 2.302763
iteration 2700 / 3000: loss 2.302647
iteration 2800 / 3000: loss 2.302581
iteration 2900 / 3000: loss 2.302335
```

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0.002 1e-07 150 3000 0.10042857142857142 0.079
iteration 0 / 1500: loss 2.302585
iteration 100 / 1500: loss 2.302603
iteration 200 / 1500: loss 2.302597
iteration 300 / 1500: loss 2.302547
iteration 400 / 1500: loss 2.302540
iteration 500 / 1500: loss 2.302520
iteration 600 / 1500: loss 2.302701
iteration 700 / 1500: loss 2.302650
iteration 800 / 1500: loss 2.302689
iteration 900 / 1500: loss 2.302506
iteration 1000 / 1500: loss 2.302701
iteration 1100 / 1500: loss 2.302623
iteration 1200 / 1500: loss 2.302350
iteration 1300 / 1500: loss 2.302557
iteration 1400 / 1500: loss 2.302481
0.002 1e-07 175 1500 0.10042857142857142 0.079
iteration 0 / 3000: loss 2.302585
iteration 100 / 3000: loss 2.302570
iteration 200 / 3000: loss 2.302630
iteration 300 / 3000: loss 2.302594
iteration 400 / 3000: loss 2.302570
iteration 500 / 3000: loss 2.302643
iteration 600 / 3000: loss 2.302646
iteration 700 / 3000: loss 2.302613
iteration 800 / 3000: loss 2.302608
iteration 900 / 3000: loss 2.302604
iteration 1000 / 3000: loss 2.302671
iteration 1100 / 3000: loss 2.302721
iteration 1200 / 3000: loss 2.302441
iteration 1300 / 3000: loss 2.302680
iteration 1400 / 3000: loss 2.302514
iteration 1500 / 3000: loss 2.302565
iteration 1600 / 3000: loss 2.302696
iteration 1700 / 3000: loss 2.302617
iteration 1800 / 3000: loss 2.302794
iteration 1900 / 3000: loss 2.302595
iteration 2000 / 3000: loss 2.302544
iteration 2100 / 3000: loss 2.302607
iteration 2200 / 3000: loss 2.302527
iteration 2300 / 3000: loss 2.302755
iteration 2400 / 3000: loss 2.302579
iteration 2500 / 3000: loss 2.302476
iteration 2600 / 3000: loss 2.302660
iteration 2700 / 3000: loss 2.302676
iteration 2800 / 3000: loss 2.302607
iteration 2900 / 3000: loss 2.302570
0.002 1e-07 175 3000 0.10026530612244898 0.087
iteration 0 / 1500: loss 2.302585
iteration 100 / 1500: loss 2.302591
iteration 200 / 1500: loss 2.302597
iteration 300 / 1500: loss 2.302583
iteration 400 / 1500: loss 2.302533
iteration 500 / 1500: loss 2.302484
iteration 600 / 1500: loss 2.302482
iteration 700 / 1500: loss 2.302593
iteration 800 / 1500: loss 2.302693
iteration 900 / 1500: loss 2.302502
iteration 1000 / 1500: loss 2.302777
iteration 1100 / 1500: loss 2.302601
```

```
               iteration 1200 / 1500: loss 2.302549
               iteration 1300 / 1500: loss 2.302636
               iteration 1400 / 1500: loss 2.302662
               0.002 2e-05 100 1500 0.10042857142857142 0.079
               iteration 0 / 3000: loss 2.302585
               iteration 100 / 3000: loss 2.302579
               iteration 200 / 3000: loss 2.302597
               iteration 300 / 3000: loss 2.302641
               iteration 400 / 3000: loss 2.302533
               iteration 500 / 3000: loss 2.302470
               iteration 600 / 3000: loss 2.302508
               iteration 700 / 3000: loss 2.302558
               iteration 800 / 3000: loss 2.302607
               iteration 900 / 3000: loss 2.302523
               iteration 1000 / 3000: loss 2.302558
               iteration 1100 / 3000: loss 2.302545
               iteration 1200 / 3000: loss 2.302477
               iteration 1300 / 3000: loss 2.302635
               iteration 1400 / 3000: loss 2.302544
               iteration 1500 / 3000: loss 2.302573
               iteration 1600 / 3000: loss 2.302606
               iteration 1700 / 3000: loss 2.302544
               iteration 1800 / 3000: loss 2.302621
               iteration 1900 / 3000: loss 2.302547
               iteration 2000 / 3000: loss 2.302579
               iteration 2100 / 3000: loss 2.302634
               iteration 2200 / 3000: loss 2.302504
               iteration 2300 / 3000: loss 2.302654
               iteration 2400 / 3000: loss 2.302525
               iteration 2500 / 3000: loss 2.302428
               iteration 2600 / 3000: loss 2.302682
               iteration 2700 / 3000: loss 2.302359
               iteration 2800 / 3000: loss 2.302484
               iteration 2900 / 3000: loss 2.302696
               0.002 2e-05 100 3000 0.10042857142857142 0.079
               iteration 0 / 1500: loss 2.302585
               iteration 100 / 1500: loss 2.302532
               iteration 200 / 1500: loss 2.302548
               iteration 300 / 1500: loss 2.302577
               iteration 400 / 1500: loss 2.302604
               iteration 500 / 1500: loss 2.302627
               iteration 600 / 1500: loss 2.302595
               iteration 700 / 1500: loss 2.302599
               iteration 800 / 1500: loss 2.302627
               iteration 900 / 1500: loss 2.302574
               iteration 1000 / 1500: loss 2.302630
               iteration 1100 / 1500: loss 2.302559
               iteration 1200 / 1500: loss 2.302564
               iteration 1300 / 1500: loss 2.302619
               iteration 1400 / 1500: loss 2.302538
               0.002 2e-05 150 1500 0.09985714285714285 0.107
               iteration 0 / 3000: loss 2.302585
               iteration 100 / 3000: loss 2.302601
               iteration 200 / 3000: loss 2.302580
               iteration 300 / 3000: loss 2.302550
               iteration 400 / 3000: loss 2.302628
               iteration 500 / 3000: loss 2.302581
               iteration 600 / 3000: loss 2.302602
               iteration 700 / 3000: loss 2.302615
               iteration 800 / 3000: loss 2.302612
```

```
iteration 900 / 3000: loss 2.302533
iteration 1000 / 3000: loss 2.302445
iteration 1100 / 3000: loss 2.302469
iteration 1200 / 3000: loss 2.302497
iteration 1300 / 3000: loss 2.302539
iteration 1400 / 3000: loss 2.302647
iteration 1500 / 3000: loss 2.302631
iteration 1600 / 3000: loss 2.302613
iteration 1700 / 3000: loss 2.302610
iteration 1800 / 3000: loss 2.302764
iteration 1900 / 3000: loss 2.302512
iteration 2000 / 3000: loss 2.302595
iteration 2100 / 3000: loss 2.302700
iteration 2200 / 3000: loss 2.302373
iteration 2300 / 3000: loss 2.302648
iteration 2400 / 3000: loss 2.302673
iteration 2500 / 3000: loss 2.302463
iteration 2600 / 3000: loss 2.302557
iteration 2700 / 3000: loss 2.302611
iteration 2800 / 3000: loss 2.302531
iteration 2900 / 3000: loss 2.302550
0.002 2e-05 150 3000 0.10044897959183674 0.078
iteration 0 / 1500: loss 2.302585
iteration 100 / 1500: loss 2.302608
iteration 200 / 1500: loss 2.302597
iteration 300 / 1500: loss 2.302553
iteration 400 / 1500: loss 2.302422
iteration 500 / 1500: loss 2.302544
iteration 600 / 1500: loss 2.302437
iteration 700 / 1500: loss 2.302565
iteration 800 / 1500: loss 2.302633
iteration 900 / 1500: loss 2.302391
iteration 1000 / 1500: loss 2.302695
iteration 1100 / 1500: loss 2.302614
iteration 1200 / 1500: loss 2.302506
iteration 1300 / 1500: loss 2.302456
iteration 1400 / 1500: loss 2.302767
0.002 2e-05 175 1500 0.09973469387755102 0.113
iteration 0 / 3000: loss 2.302585
iteration 100 / 3000: loss 2.302632
iteration 200 / 3000: loss 2.302558
iteration 300 / 3000: loss 2.302522
iteration 400 / 3000: loss 2.302640
iteration 500 / 3000: loss 2.302658
iteration 600 / 3000: loss 2.302640
iteration 700 / 3000: loss 2.302646
iteration 800 / 3000: loss 2.302487
iteration 900 / 3000: loss 2.302505
iteration 1000 / 3000: loss 2.302634
iteration 1100 / 3000: loss 2.302687
iteration 1200 / 3000: loss 2.302752
iteration 1300 / 3000: loss 2.302464
iteration 1400 / 3000: loss 2.302605
iteration 1500 / 3000: loss 2.302570
iteration 1600 / 3000: loss 2.302541
iteration 1700 / 3000: loss 2.302626
iteration 1800 / 3000: loss 2.302587
iteration 1900 / 3000: loss 2.302490
iteration 2000 / 3000: loss 2.302645
iteration 2100 / 3000: loss 2.302543
```

```
iteration 2200 / 3000: loss 2.302546
iteration 2300 / 3000: loss 2.302656
iteration 2400 / 3000: loss 2.302649
iteration 2500 / 3000: loss 2.302740
iteration 2600 / 3000: loss 2.302476
iteration 2700 / 3000: loss 2.302659
iteration 2800 / 3000: loss 2.302540
iteration 2900 / 3000: loss 2.302452
0.002 2e-05 175 3000 0.10044897959183674 0.078
```

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

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

```
0.573
```