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))
  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 5.2 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)
```

```
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)
     ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 59.1/59.1 kB 6.5 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)
```

```
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
```

```
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 6.9 MB/s eta 0:00:00
Downloading asttokens-2.2.1-py2.py3-none-any.whl (26 kB)
Downloading async_lru-2.0.4-py3-none-any.whl (6.1 kB)
Downloading attrs-23.1.0-py3-none-any.whl (61 kB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 61.2/61.2 kB 6.3 MB/s eta 0:00:00
Downloading Babel-2.12.1-py3-none-any.whl (10.1 MB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 10.1/10.1 MB 53.4 MB/s eta 0:00:00
Downloading beautifulsoup4-4.12.2-py3-none-any.whl (142 kB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 143.0/143.0 kB 15.0 MB/s eta 0:00:00
Downloading bleach-6.0.0-py3-none-any.whl (162 kB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 162.5/162.5 kB 15.7 MB/s eta 0:00:00
Downloading certifi-2023.7.22-py3-none-any.whl (158 kB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 158.3/158.3 kB 15.9 MB/s eta 0:00:00
Downloading cffi-1.15.1-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.whl (4
41 kB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 441.8/441.8 kB 30.0 MB/s eta 0:00:00
Downloading charset_normalizer-3.2.0-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_
x86_64.whl (201 kB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 201.8/201.8 kB 19.0 MB/s eta 0:00:00
Downloading comm-0.1.4-py3-none-any.whl (6.6 kB)
Downloading contourpy-1.1.0-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.wh
l (300 kB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 300.7/300.7 kB 23.7 MB/s eta 0:00:00
Downloading cycler-0.11.0-py3-none-any.whl (6.4 kB)
Downloading debugpy-1.6.7.post1-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_6
4.whl (3.0 MB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 3.0/3.0 MB 53.9 MB/s eta 0:00:00
Downloading executing-1.2.0-py2.py3-none-any.whl (24 kB)
Downloading fastjsonschema-2.18.0-py3-none-any.whl (23 kB)
Downloading fonttools-4.42.1-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.w
hl (4.5 MB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 4.5/4.5 MB 36.4 MB/s eta 0:00:00
Downloading fqdn-1.5.1-py3-none-any.whl (9.1 kB)
Downloading idna-3.4-py3-none-any.whl (61 kB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 61.5/61.5 kB 6.3 MB/s eta 0:00:00
Downloading imageio-2.31.1-py3-none-any.whl (313 kB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 313.2/313.2 kB 25.8 MB/s eta 0:00:00
Downloading isoduration-20.11.0-py3-none-any.whl (11 kB)
Downloading jedi-0.19.0-py2.py3-none-any.whl (1.6 MB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 1.6/1.6 MB 57.9 MB/s eta 0:00:00
Downloading Jinja2-3.1.2-py3-none-any.whl (133 kB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 133.1/133.1 kB 13.8 MB/s eta 0:00:00
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)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 83.4/83.4 kB 7.6 MB/s eta 0:00:00
Downloading jsonschema_specifications-2023.7.1-py3-none-any.whl (17 kB)
Downloading jupyter_events-0.7.0-py3-none-any.whl (18 kB)
Downloading jupyter_lsp-2.2.0-py3-none-any.whl (65 kB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 66.0/66.0 kB 7.3 MB/s eta 0:00:00
Downloading jupyter_core-5.3.1-py3-none-any.whl (93 kB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 93.7/93.7 kB 10.3 MB/s eta 0:00:00
Downloading jupyter_server-2.7.2-py3-none-any.whl (375 kB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 375.3/375.3 kB 28.5 MB/s eta 0:00:00
```

```
Downloading jupyter_server_terminals-0.4.4-py3-none-any.whl (13 kB)
Downloading jupyterlab-4.0.5-py3-none-any.whl (9.2 MB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 9.2/9.2 MB 65.6 MB/s eta 0:00:00
Downloading jupyterlab_pygments-0.2.2-py2.py3-none-any.whl (21 kB)
Downloading jupyterlab_server-2.24.0-py3-none-any.whl (57 kB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 57.3/57.3 kB 6.3 MB/s eta 0:00:00
Downloading kiwisolver-1.4.5-cp310-cp310-manylinux_2_12_x86_64.manylinux2010_x86_64.w
hl (1.6 MB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 1.6/1.6 MB 54.1 MB/s eta 0:00:00
Downloading MarkupSafe-2.1.3-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.w
hl (25 kB)
Downloading matplotlib-3.7.2-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.w
hl (11.6 MB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 11.6/11.6 MB 61.4 MB/s eta 0:00:00
Downloading matplotlib_inline-0.1.6-py3-none-any.whl (9.4 kB)
Downloading mistune-3.0.1-py3-none-any.whl (47 kB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 48.0/48.0 kB 4.0 MB/s eta 0:00:00
Downloading nbclient-0.8.0-py3-none-any.whl (73 kB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 73.1/73.1 kB 5.5 MB/s eta 0:00:00
Downloading nbconvert-7.7.4-py3-none-any.whl (254 kB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 254.6/254.6 kB 19.9 MB/s eta 0:00:00
Downloading nbformat-5.9.2-py3-none-any.whl (77 kB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 77.6/77.6 kB 8.1 MB/s eta 0:00:00
Downloading nest_asyncio-1.5.7-py3-none-any.whl (5.3 kB)
Downloading notebook_shim-0.2.3-py3-none-any.whl (13 kB)
Downloading overrides-7.4.0-py3-none-any.whl (17 kB)
Downloading packaging-23.1-py3-none-any.whl (48 kB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 48.9/48.9 kB 4.0 MB/s eta 0:00:00
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)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 100.8/100.8 kB 10.4 MB/s eta 0:00:00
Downloading pexpect-4.8.0-py2.py3-none-any.whl (59 kB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 59.0/59.0 kB 5.1 MB/s eta 0:00:00
Downloading Pillow-10.0.0-cp310-cp310-manylinux_2_28_x86_64.whl (3.4 MB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 3.4/3.4 MB 59.9 MB/s eta 0:00:00
Downloading platformdirs-3.10.0-py3-none-any.whl (17 kB)
Downloading prometheus_client-0.17.1-py3-none-any.whl (60 kB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 60.6/60.6 kB 6.3 MB/s eta 0:00:00
Downloading prompt_toolkit-3.0.39-py3-none-any.whl (385 kB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 385.2/385.2 kB 27.0 MB/s eta 0:00:00
Downloading pure_eval-0.2.2-py3-none-any.whl (11 kB)
Downloading pycparser-2.21-py2.py3-none-any.whl (118 kB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 118.7/118.7 kB 13.1 MB/s eta 0:00:00
Downloading Pygments-2.16.1-py3-none-any.whl (1.2 MB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 1.2/1.2 MB 11.3 MB/s eta 0:00:00
Downloading pyparsing-3.0.9-py3-none-any.whl (98 kB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 98.3/98.3 kB 9.9 MB/s eta 0:00:00
Downloading python_json_logger-2.0.7-py3-none-any.whl (8.1 kB)
Downloading pytz-2023.3-py2.py3-none-any.whl (502 kB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 502.3/502.3 kB 30.3 MB/s eta 0:00:00
Downloading PyYAML-6.0.1-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.whl
(705 kB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 705.5/705.5 kB 39.7 MB/s eta 0:00:00
Downloading referencing-0.30.2-py3-none-any.whl (25 kB)
Downloading requests-2.31.0-py3-none-any.whl (62 kB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 62.6/62.6 kB 6.5 MB/s eta 0:00:00
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
(1.2 MB)
```

```
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 1.2/1.2 MB 47.2 MB/s eta 0:00:00
Downloading scipy-1.11.2-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.whl
(36.3 MB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 36.3/36.3 MB 24.9 MB/s eta 0:00:00
Downloading seaborn-0.12.2-py3-none-any.whl (293 kB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 293.3/293.3 kB 26.8 MB/s eta 0:00:00
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)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 117.4/117.4 kB 12.9 MB/s eta 0:00:00
Downloading tzdata-2023.3-py2.py3-none-any.whl (341 kB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 341.8/341.8 kB 29.2 MB/s eta 0:00:00
Downloading uri_template-1.3.0-py3-none-any.whl (11 kB)
Downloading urllib3-2.0.4-py3-none-any.whl (123 kB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 123.9/123.9 kB 12.1 MB/s eta 0:00:00
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)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 57.0/57.0 kB 6.1 MB/s eta 0:00:00
Downloading jupyter_client-7.4.9-py3-none-any.whl (133 kB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 133.5/133.5 kB 13.9 MB/s eta 0:00:00
Downloading numpy-1.23.5-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.whl
(17.1 MB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 17.1/17.1 MB 78.3 MB/s eta 0:00:00
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)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 426.9/426.9 kB 32.6 MB/s eta 0:00:00
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
```

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

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
```

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 [ ]:

```
# 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 [ ]:

```
# 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:                                                                        #
```

```
# 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.

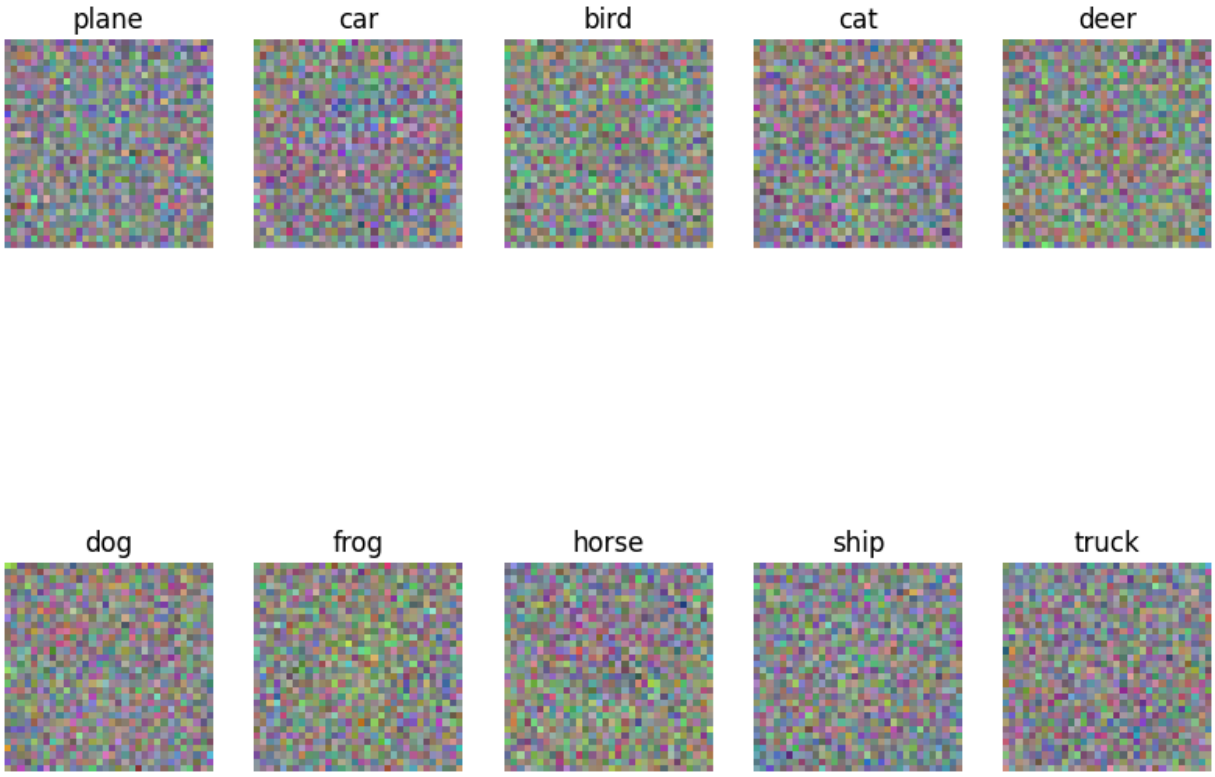
Your answer: True.

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])
```