softmax

December 12, 2024

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

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

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

# This downloads the CIFAR-10 dataset to your Drive
# if it doesn't already exist.
%cd /content/drive/My\ Drive/$FOLDERNAME/cs6353/datasets/
!bash get_datasets.sh
%cd /content/drive/My\ Drive/$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/cs6353/datasets
--2024-12-06 06:04:50--  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  33.9MB/s    in 5.1s
```

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2024-12-06 06:04:56 (31.9 MB/s) - ‘cifar-10-python.tar.gz’ saved
[170498071/170498071]

cifar-10-batches-py/
cifar-10-batches-py/data_batch_4
cifar-10-batches-py/readme.html
cifar-10-batches-py/test_batch
cifar-10-batches-py/data_batch_3
cifar-10-batches-py/batches.meta
cifar-10-batches-py/data_batch_2
cifar-10-batches-py/data_batch_5
cifar-10-batches-py/data_batch_1
/content/drive/My Drive/cs6353/assignments/assignment2
Requirement already satisfied: anyio==3.7.1 in /usr/local/lib/python3.10/dist-
packages (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 1)) (3.7.1)
Collecting appnope==0.1.3 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 2))
  Downloading appnope-0.1.3-py2.py3-none-any.whl.metadata (1.2 kB)
Requirement already satisfied: argon2-cffi==23.1.0 in
/usr/local/lib/python3.10/dist-packages (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 3)) (23.1.0)
Requirement already satisfied: argon2-cffi-bindings==21.2.0 in
/usr/local/lib/python3.10/dist-packages (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 4)) (21.2.0)
Collecting arrow==1.2.3 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 5))
  Downloading arrow-1.2.3-py3-none-any.whl.metadata (6.9 kB)
Collecting asttokens==2.2.1 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 6))
  Downloading asttokens-2.2.1-py2.py3-none-any.whl.metadata (4.8 kB)
Collecting async-lru==2.0.4 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 7))
  Downloading async_lru-2.0.4-py3-none-any.whl.metadata (4.5 kB)
Collecting attrs==23.1.0 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 8))
  Downloading attrs-23.1.0-py3-none-any.whl.metadata (11 kB)
Collecting Babel==2.12.1 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 9))
  Downloading Babel-2.12.1-py3-none-any.whl.metadata (1.3 kB)
Requirement already satisfied: backcall==0.2.0 in
/usr/local/lib/python3.10/dist-packages (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 10)) (0.2.0)
Collecting beautifulsoup4==4.12.2 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 11))
  Downloading beautifulsoup4-4.12.2-py3-none-any.whl.metadata (3.6 kB)
Collecting bleach==6.0.0 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 12))
```

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  Downloading bleach-6.0.0-py3-none-any.whl.metadata (29 kB)
Collecting certifi==2023.7.22 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 13))
  Downloading certifi-2023.7.22-py3-none-any.whl.metadata (2.2 kB)
Collecting cffi==1.15.1 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 14))
  Downloading
cffi-1.15.1-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.whl.metadata
(1.1 kB)
Collecting charset-normalizer==3.2.0 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 15))
  Downloading charset_normalizer-3.2.0-cp310-cp310-manylinux_2_17_x86_64.manylin
ux2014_x86_64.whl.metadata (31 kB)
Collecting comm==0.1.4 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 16))
  Downloading comm-0.1.4-py3-none-any.whl.metadata (4.2 kB)
Collecting contourpy==1.1.0 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 17))
  Downloading contourpy-1.1.0-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x8
6_64.whl.metadata (5.7 kB)
Collecting cycler==0.11.0 (from -r /content/drive/My
Drive/cs6353/assignments/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/assignment2//colab_requirements.txt (line 19))
  Downloading debugpy-1.6.7.post1-cp310-cp310-manylinux_2_17_x86_64.manylinux201
4_x86_64.whl.metadata (1.1 kB)
Requirement already satisfied: decorator<=5.0 in /usr/local/lib/python3.10/dist-
packages (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 20)) (4.4.2)
Requirement already satisfied: defusedxml==0.7.1 in
/usr/local/lib/python3.10/dist-packages (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 21)) (0.7.1)
Collecting executing==1.2.0 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 22))
  Downloading executing-1.2.0-py2.py3-none-any.whl.metadata (8.9 kB)
Collecting fastjsonschema==2.18.0 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 23))
  Downloading fastjsonschema-2.18.0-py3-none-any.whl.metadata (2.0 kB)
Collecting fonttools==4.42.1 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 24))
  Downloading fonttools-4.42.1-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x
86_64.whl.metadata (150 kB)
                           151.0/151.0
kB 6.4 MB/s eta 0:00:00
Collecting fqdn==1.5.1 (from -r /content/drive/My
Drive/cs6353/assignments/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//colab_requirements.txt (line 26))
  Downloading idna-3.4-py3-none-any.whl.metadata (9.8 kB)
Collecting imageio==2.31.1 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 27))
  Downloading imageio-2.31.1-py3-none-any.whl.metadata (4.7 kB)
Requirement already satisfied: ipykernel<=5.5.6 in
/usr/local/lib/python3.10/dist-packages (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 28)) (5.5.6)
Requirement already satisfied: ipython<=7.34.0 in
/usr/local/lib/python3.10/dist-packages (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 29)) (7.34.0)
Collecting isoduration==20.11.0 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 30))
  Downloading isoduration-20.11.0-py3-none-any.whl.metadata (5.7 kB)
Collecting jedi==0.19.0 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 31))
  Downloading jedi-0.19.0-py2.py3-none-any.whl.metadata (22 kB)
Collecting Jinja2==3.1.2 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 32))
  Downloading Jinja2-3.1.2-py3-none-any.whl.metadata (3.5 kB)
Collecting json5==0.9.14 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 33))
  Downloading json5-0.9.14-py2.py3-none-any.whl.metadata (10 kB)
Collecting jsonpointer==2.4 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 34))
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Collecting jsonschema==4.19.0 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 35))
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Collecting jsonschema-specifications==2023.7.1 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 36))
  Downloading jsonschema_specifications-2023.7.1-py3-none-any.whl.metadata (2.8
kB)
Collecting jupyter-events==0.7.0 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 37))
  Downloading jupyter_events-0.7.0-py3-none-any.whl.metadata (5.5 kB)
Collecting jupyter-lsp==2.2.0 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 38))
  Downloading jupyter_lsp-2.2.0-py3-none-any.whl.metadata (1.8 kB)
Requirement already satisfied: jupyter_client<8.0 in
/usr/local/lib/python3.10/dist-packages (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 39)) (6.1.12)
Collecting jupyter_core==5.3.1 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 40))
  Downloading jupyter_core-5.3.1-py3-none-any.whl.metadata (3.4 kB)
Collecting jupyter_server==2.7.2 (from -r /content/drive/My
```

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Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 41))
  Downloading jupyter_server-2.7.2-py3-none-any.whl.metadata (8.6 kB)
Collecting jupyter_server_terminals==0.4.4 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 42))
  Downloading jupyter_server_terminals-0.4.4-py3-none-any.whl.metadata (6.3 kB)
Collecting jupyterlab==4.0.5 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 43))
  Downloading jupyterlab-4.0.5-py3-none-any.whl.metadata (15 kB)
Collecting jupyterlab-pygments==0.2.2 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 44))
  Downloading jupyterlab_pygments-0.2.2-py2.py3-none-any.whl.metadata (1.9 kB)
Collecting jupyterlab_server==2.24.0 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 45))
  Downloading jupyterlab_server-2.24.0-py3-none-any.whl.metadata (5.8 kB)
Collecting kiwisolver==1.4.5 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 46))
  Downloading kiwisolver-1.4.5-cp310-cp310-manylinux_2_12_x86_64.manylinux2010_x
86_64.whl.metadata (6.4 kB)
Collecting MarkupSafe==2.1.3 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 47))
  Downloading MarkupSafe-2.1.3-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x
86_64.whl.metadata (3.0 kB)
Collecting matplotlib==3.7.2 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 48))
  Downloading matplotlib-3.7.2-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x
86_64.whl.metadata (5.6 kB)
Collecting matplotlib-inline==0.1.6 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 49))
  Downloading matplotlib_inline-0.1.6-py3-none-any.whl.metadata (2.8 kB)
Collecting mistune==3.0.1 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 50))
  Downloading mistune-3.0.1-py3-none-any.whl.metadata (1.7 kB)
Collecting nbclient==0.8.0 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 51))
  Downloading nbclient-0.8.0-py3-none-any.whl.metadata (7.8 kB)
Collecting nbconvert==7.7.4 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 52))
  Downloading nbconvert-7.7.4-py3-none-any.whl.metadata (8.0 kB)
Collecting nbformat==5.9.2 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 53))
  Downloading nbformat-5.9.2-py3-none-any.whl.metadata (3.4 kB)
Collecting nest-asyncio==1.5.7 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 54))
  Downloading nest_asyncio-1.5.7-py3-none-any.whl.metadata (2.7 kB)
Collecting notebook_shim==0.2.3 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 55))
  Downloading notebook_shim-0.2.3-py3-none-any.whl.metadata (4.0 kB)
Collecting numpy<1.24,>=1.22 (from -r /content/drive/My
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Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 56))
  Downloading
numpy-1.23.5-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.whl.metadata
(2.3 kB)
Collecting overrides==7.4.0 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 57))
  Downloading overrides-7.4.0-py3-none-any.whl.metadata (5.7 kB)
Collecting packaging==23.1 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 58))
  Downloading packaging-23.1-py3-none-any.whl.metadata (3.1 kB)
Collecting pandas<=1.5.3 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 59))
  Downloading
pandas-1.5.3-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.whl.metadata
(11 kB)
Collecting pandocfilters==1.5.0 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 60))
  Downloading pandocfilters-1.5.0-py2.py3-none-any.whl.metadata (9.0 kB)
Collecting parso==0.8.3 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 61))
  Downloading parso-0.8.3-py2.py3-none-any.whl.metadata (7.5 kB)
Collecting pexpect==4.8.0 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 62))
  Downloading pexpect-4.8.0-py2.py3-none-any.whl.metadata (2.2 kB)
Requirement already satisfied: pickleshare==0.7.5 in
/usr/local/lib/python3.10/dist-packages (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 63)) (0.7.5)
Collecting Pillow==10.0.0 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 64))
  Downloading Pillow-10.0.0-cp310-cp310-manylinux_2_28_x86_64.whl.metadata (9.5
kB)
Collecting platformdirs==3.10.0 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 65))
  Downloading platformdirs-3.10.0-py3-none-any.whl.metadata (11 kB)
Collecting prometheus-client==0.17.1 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 66))
  Downloading prometheus_client-0.17.1-py3-none-any.whl.metadata (24 kB)
Collecting prompt-toolkit==3.0.39 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 67))
  Downloading prompt_toolkit-3.0.39-py3-none-any.whl.metadata (6.4 kB)
Requirement already satisfied: psutil==5.9.5 in /usr/local/lib/python3.10/dist-
packages (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 68)) (5.9.5)
Requirement already satisfied: ptyprocess==0.7.0 in
/usr/local/lib/python3.10/dist-packages (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 69)) (0.7.0)
Collecting pure-eval==0.2.2 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 70))
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  Downloading pure_eval-0.2.2-py3-none-any.whl.metadata (6.2 kB)
Collecting pycparser==2.21 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 71))
  Downloading pycparser-2.21-py2.py3-none-any.whl.metadata (1.1 kB)
Collecting Pygments==2.16.1 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 72))
  Downloading Pygments-2.16.1-py3-none-any.whl.metadata (2.5 kB)
Collecting pyparsing==3.0.9 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 73))
  Downloading pyparsing-3.0.9-py3-none-any.whl.metadata (4.2 kB)
Requirement already satisfied: python-dateutil==2.8.2 in
/usr/local/lib/python3.10/dist-packages (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 74)) (2.8.2)
Collecting python-json-logger==2.0.7 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 75))
  Downloading python_json_logger-2.0.7-py3-none-any.whl.metadata (6.5 kB)
Collecting pytz==2023.3 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 76))
  Downloading pytz-2023.3-py2.py3-none-any.whl.metadata (22 kB)
Collecting PyYAML==6.0.1 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 77))
  Downloading
PyYAML-6.0.1-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.whl.metadata
(2.1 kB)
Requirement already satisfied: pyzmq<25 in /usr/local/lib/python3.10/dist-
packages (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 78)) (24.0.1)
Collecting referencing==0.30.2 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 79))
  Downloading referencing-0.30.2-py3-none-any.whl.metadata (2.6 kB)
Collecting requests==2.31.0 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 80))
  Downloading requests-2.31.0-py3-none-any.whl.metadata (4.6 kB)
Collecting rfc3339-validator==0.1.4 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 81))
  Downloading rfc3339_validator-0.1.4-py2.py3-none-any.whl.metadata (1.5 kB)
Collecting rfc3986-validator==0.1.1 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 82))
  Downloading rfc3986_validator-0.1.1-py2.py3-none-any.whl.metadata (1.7 kB)
Collecting rpds-py==0.9.2 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 83))
  Downloading rpds_py-0.9.2-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_
64.whl.metadata (3.7 kB)
Collecting scipy==1.11.2 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 84))
  Downloading
scipy-1.11.2-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.whl.metadata
(59 kB)
```

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                                     59.1/59.1 kB
4.3 MB/s eta 0:00:00
Collecting seaborn==0.12.2 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 85))
  Downloading seaborn-0.12.2-py3-none-any.whl.metadata (5.4 kB)
Collecting Send2Trash==1.8.2 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 86))
  Downloading Send2Trash-1.8.2-py3-none-any.whl.metadata (4.0 kB)
Requirement already satisfied: six==1.16.0 in /usr/local/lib/python3.10/dist-
packages (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 87)) (1.16.0)
Collecting sniffio==1.3.0 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 88))
  Downloading sniffio-1.3.0-py3-none-any.whl.metadata (3.6 kB)
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Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 89))
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Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 92))
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Collecting tornado<=6.3.2 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 93))
  Downloading tornado-6.3.2-cp38-abi3-manylinux_2_5_x86_64.manylinux1_x86_64.man
ylinux_2_17_x86_64.manylinux2014_x86_64.whl.metadata (2.5 kB)
Collecting traitlets==5.9.0 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 94))
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Collecting tzdata==2023.3 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 95))
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Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 96))
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Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 97))
  Downloading urllib3-2.0.4-py3-none-any.whl.metadata (6.6 kB)
Collecting wcwidth==0.2.6 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 98))
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Collecting webcolors==1.13 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 99))
  Downloading webcolors-1.13-py3-none-any.whl.metadata (2.6 kB)
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Requirement already satisfied: webencodings==0.5.1 in
/usr/local/lib/python3.10/dist-packages (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 100)) (0.5.1)
Collecting websocket-client==1.6.2 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 101))
  Downloading websocket_client-1.6.2-py3-none-any.whl.metadata (7.5 kB)
Requirement already satisfied: exceptiongroup in /usr/local/lib/python3.10/dist-
packages (from anyio==3.7.1->-r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 1)) (1.2.2)
Requirement already satisfied: typing-extensions>=4.0.0 in
/usr/local/lib/python3.10/dist-packages (from async-lru==2.0.4->-r
/content/drive/My Drive/cs6353/assignments/assignment2//colab_requirements.txt
(line 7)) (4.12.2)
Collecting jupyter_client<8.0 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 39))
  Downloading jupyter_client-7.4.9-py3-none-any.whl.metadata (8.5 kB)
Requirement already satisfied: tomli in /usr/local/lib/python3.10/dist-packages
(from jupyterlab==4.0.5->-r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 43)) (2.2.1)
Requirement already satisfied: ipython-genutils in
/usr/local/lib/python3.10/dist-packages (from ipykernel<=5.5.6->-r
/content/drive/My Drive/cs6353/assignments/assignment2//colab_requirements.txt
(line 28)) (0.2.0)
Requirement already satisfied: setuptools>=18.5 in
/usr/local/lib/python3.10/dist-packages (from ipython<=7.34.0->-r
/content/drive/My Drive/cs6353/assignments/assignment2//colab_requirements.txt
(line 29)) (75.1.0)
Requirement already satisfied: entrypoints in /usr/local/lib/python3.10/dist-
packages (from jupyter_client<8.0->-r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 39)) (0.4)
Downloading appnope-0.1.3-py2.py3-none-any.whl (4.4 kB)
Downloading arrow-1.2.3-py3-none-any.whl (66 kB)
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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)
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cffi-1.15.1-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.whl (441 kB)
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ylinux2014_x86_64.whl (201 kB)
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contourpy-1.1.0-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.whl (300
kB)
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Downloading cycler-0.11.0-py3-none-any.whl (6.4 kB)
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debugpy-1.6.7.post1-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.whl
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Downloading executing-1.2.0-py2.py3-none-any.whl (24 kB)
Downloading fastjsonschema-2.18.0-py3-none-any.whl (23 kB)
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Downloading fqdn-1.5.1-py3-none-any.whl (9.1 kB)
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Downloading jsonpointer-2.4-py2.py3-none-any.whl (7.8 kB)
Downloading jsonschema-4.19.0-py3-none-any.whl (83 kB)
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kiwisolver-1.4.5-cp310-cp310-manylinux_2_12_x86_64.manylinux2010_x86_64.whl (1.6
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scipy-1.11.2-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.whl (36.3
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Downloading soupsieve-2.4.1-py3-none-any.whl (36 kB)
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Downloading terminado-0.17.1-py3-none-any.whl (17 kB)
Downloading tinycss2-1.2.1-py3-none-any.whl (21 kB)
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pandas-1.5.3-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.whl (12.1
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.manylinux_2_17_x86_64.manylinux2014_x86_64.whl (426 kB)
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Installing collected packages: wcwidth, pytz, pure-eval, json5,
fastjsonschema, executing, appnope, websocket-client, webcolors, urllib3, uri-
template, tzdata, traitlets, tornado, tinycss2, soupsieve, sniffio, Send2Trash,
rpds-py, rfc3986-validator, rfc3339-validator, PyYAML, python-json-logger,
pyparsing, Pygments, pycparser, prompt-toolkit, prometheus-client, platformdirs,
Pillow, pexpect, parso, pandocfilters, packaging, overrides, numpy, nest-
asyncio, mistune, MarkupSafe, kiwisolver, jupyterlab-pygments, jsonpointer,
idna, fqdn, fonttools, debugpy, cycler, charset-normalizer, certifi, bleach,
Babel, attrs, async-lru, asttokens, terminado, stack-data, scipy, requests,
referencing, pandas, matplotlib-inline, jupyter_core, Jinja2, jedi, imageio,
contourpy, comm, cffi, beautifulsoup4, arrow, matplotlib,
jupyter_server_terminals, jupyter_client, jsonschema-specifications,
isoduration, seaborn, jsonschema, nbformat, nbclient, jupyter-events, nbconvert,
jupyter_server, notebook_shim, jupyterlab_server, jupyter-lsp, jupyterlab
  Attempting uninstall: wcwidth
    Found existing installation: wcwidth 0.2.13
    Uninstalling wcwidth-0.2.13:
      Successfully uninstalled wcwidth-0.2.13
  Attempting uninstall: pytz
    Found existing installation: pytz 2024.2
    Uninstalling pytz-2024.2:
      Successfully uninstalled pytz-2024.2
  Attempting uninstall: fastjsonschema
    Found existing installation: fastjsonschema 2.21.1
    Uninstalling fastjsonschema-2.21.1:
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  Attempting uninstall: websocket-client
    Found existing installation: websocket-client 1.8.0
    Uninstalling websocket-client-1.8.0:
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  Attempting uninstall: webcolors
    Found existing installation: webcolors 24.11.1
    Uninstalling webcolors-24.11.1:
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  Attempting uninstall: urllib3
    Found existing installation: urllib3 2.2.3
    Uninstalling urllib3-2.2.3:
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  Attempting uninstall: tzdata
    Found existing installation: tzdata 2024.2
    Uninstalling tzdata-2024.2:
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  Attempting uninstall: traitlets
    Found existing installation: traitlets 5.7.1
    Uninstalling traitlets-5.7.1:
      Successfully uninstalled traitlets-5.7.1
  Attempting uninstall: tornado
    Found existing installation: tornado 6.3.3
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  Uninstalling tornado-6.3.3:
    Successfully uninstalled tornado-6.3.3
Attempting uninstall: tinycss2
  Found existing installation: tinycss2 1.4.0
  Uninstalling tinycss2-1.4.0:
    Successfully uninstalled tinycss2-1.4.0
Attempting uninstall: soupsieve
  Found existing installation: soupsieve 2.6
  Uninstalling soupsieve-2.6:
    Successfully uninstalled soupsieve-2.6
Attempting uninstall: sniffio
  Found existing installation: sniffio 1.3.1
  Uninstalling sniffio-1.3.1:
    Successfully uninstalled sniffio-1.3.1
Attempting uninstall: Send2Trash
  Found existing installation: Send2Trash 1.8.3
  Uninstalling Send2Trash-1.8.3:
    Successfully uninstalled Send2Trash-1.8.3
Attempting uninstall: rpds-py
  Found existing installation: rpds-py 0.22.0
  Uninstalling rpds-py-0.22.0:
    Successfully uninstalled rpds-py-0.22.0
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 3.2.0
  Uninstalling pyparsing-3.2.0:
    Successfully uninstalled pyparsing-3.2.0
Attempting uninstall: Pygments
  Found existing installation: Pygments 2.18.0
  Uninstalling Pygments-2.18.0:
    Successfully uninstalled Pygments-2.18.0
Attempting uninstall: pycparser
  Found existing installation: pycparser 2.22
  Uninstalling pycparser-2.22:
    Successfully uninstalled pycparser-2.22
Attempting uninstall: prompt-toolkit
  Found existing installation: prompt_toolkit 3.0.48
  Uninstalling prompt_toolkit-3.0.48:
    Successfully uninstalled prompt_toolkit-3.0.48
Attempting uninstall: prometheus-client
  Found existing installation: prometheus_client 0.21.0
  Uninstalling prometheus_client-0.21.0:
    Successfully uninstalled prometheus_client-0.21.0
Attempting uninstall: platformdirs
  Found existing installation: platformdirs 4.3.6
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  Uninstalling platformdirs-4.3.6:
    Successfully uninstalled platformdirs-4.3.6
Attempting uninstall: Pillow
  Found existing installation: pillow 11.0.0
  Uninstalling pillow-11.0.0:
    Successfully uninstalled pillow-11.0.0
Attempting uninstall: pexpect
  Found existing installation: pexpect 4.9.0
  Uninstalling pexpect-4.9.0:
    Successfully uninstalled pexpect-4.9.0
Attempting uninstall: parso
  Found existing installation: parso 0.8.4
  Uninstalling parso-0.8.4:
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Attempting uninstall: pandocfilters
  Found existing installation: pandocfilters 1.5.1
  Uninstalling pandocfilters-1.5.1:
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Attempting uninstall: packaging
  Found existing installation: packaging 24.2
  Uninstalling packaging-24.2:
    Successfully uninstalled packaging-24.2
Attempting uninstall: numpy
  Found existing installation: numpy 1.26.4
  Uninstalling numpy-1.26.4:
    Successfully uninstalled numpy-1.26.4
Attempting uninstall: nest-asyncio
  Found existing installation: nest-asyncio 1.6.0
  Uninstalling nest-asyncio-1.6.0:
    Successfully uninstalled nest-asyncio-1.6.0
Attempting uninstall: mistune
  Found existing installation: mistune 3.0.2
  Uninstalling mistune-3.0.2:
    Successfully uninstalled mistune-3.0.2
Attempting uninstall: MarkupSafe
  Found existing installation: MarkupSafe 3.0.2
  Uninstalling MarkupSafe-3.0.2:
    Successfully uninstalled MarkupSafe-3.0.2
Attempting uninstall: kiwisolver
  Found existing installation: kiwisolver 1.4.7
  Uninstalling kiwisolver-1.4.7:
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Attempting uninstall: jupyterlab-pygments
  Found existing installation: jupyterlab_pygments 0.3.0
  Uninstalling jupyterlab_pygments-0.3.0:
    Successfully uninstalled jupyterlab_pygments-0.3.0
Attempting uninstall: jsonpointer
  Found existing installation: jsonpointer 3.0.0
```

```
  Uninstalling jsonpointer-3.0.0:
    Successfully uninstalled jsonpointer-3.0.0
Attempting uninstall: idna
  Found existing installation: idna 3.10
  Uninstalling idna-3.10:
    Successfully uninstalled idna-3.10
Attempting uninstall: fonttools
  Found existing installation: fonttools 4.55.0
  Uninstalling fonttools-4.55.0:
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Attempting uninstall: debugpy
  Found existing installation: debugpy 1.8.0
  Uninstalling debugpy-1.8.0:
    Successfully uninstalled debugpy-1.8.0
Attempting uninstall: cycler
  Found existing installation: cycler 0.12.1
  Uninstalling cycler-0.12.1:
    Successfully uninstalled cycler-0.12.1
Attempting uninstall: charset-normalizer
  Found existing installation: charset-normalizer 3.4.0
  Uninstalling charset-normalizer-3.4.0:
    Successfully uninstalled charset-normalizer-3.4.0
Attempting uninstall: certifi
  Found existing installation: certifi 2024.8.30
  Uninstalling certifi-2024.8.30:
    Successfully uninstalled certifi-2024.8.30
Attempting uninstall: bleach
  Found existing installation: bleach 6.2.0
  Uninstalling bleach-6.2.0:
    Successfully uninstalled bleach-6.2.0
Attempting uninstall: Babel
  Found existing installation: babel 2.16.0
  Uninstalling babel-2.16.0:
    Successfully uninstalled babel-2.16.0
Attempting uninstall: attrs
  Found existing installation: attrs 24.2.0
  Uninstalling attrs-24.2.0:
    Successfully uninstalled attrs-24.2.0
Attempting uninstall: terminado
  Found existing installation: terminado 0.18.1
  Uninstalling terminado-0.18.1:
    Successfully uninstalled terminado-0.18.1
Attempting uninstall: scipy
  Found existing installation: scipy 1.13.1
  Uninstalling scipy-1.13.1:
    Successfully uninstalled scipy-1.13.1
Attempting uninstall: requests
  Found existing installation: requests 2.32.3
```

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

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

```
ERROR: pip's dependency resolver does not currently take into account all
the packages that are installed. This behaviour is the source of the following
dependency conflicts.
albucore 0.0.19 requires numpy>=1.24.4, but you have numpy 1.23.5 which is
incompatible.
albumentations 1.4.20 requires numpy>=1.24.4, but you have numpy 1.23.5 which is
incompatible.
bigframes 1.27.0 requires numpy>=1.24.0, but you have numpy 1.23.5 which is
incompatible.
bokeh 3.6.1 requires contourpy>=1.2, but you have contourpy 1.1.0 which is
incompatible.
chex 0.1.87 requires numpy>=1.24.1, but you have numpy 1.23.5 which is
incompatible.
cudf-cu12 24.10.1 requires pandas<2.2.3dev0,>=2.0, but you have pandas 1.5.3
which is incompatible.
google-colab 1.0.0 requires pandas==2.2.2, but you have pandas 1.5.3 which is
incompatible.
google-colab 1.0.0 requires requests==2.32.3, but you have requests 2.31.0 which
is incompatible.
google-colab 1.0.0 requires tornado==6.3.3, but you have tornado 6.3.2 which is
incompatible.
jax 0.4.33 requires numpy>=1.24, but you have numpy 1.23.5 which is
incompatible.
jaxlib 0.4.33 requires numpy>=1.24, but you have numpy 1.23.5 which is
incompatible.
langchain-core 0.3.21 requires packaging<25,>=23.2, but you have packaging 23.1
which is incompatible.
mizani 0.13.0 requires pandas>=2.2.0, but you have pandas 1.5.3 which is
incompatible.
plotnine 0.14.3 requires matplotlib>=3.8.0, but you have matplotlib 3.7.2 which
is incompatible.
plotnine 0.14.3 requires pandas>=2.2.0, but you have pandas 1.5.3 which is
incompatible.
pygit2 1.16.0 requires cffi>=1.17.0, but you have cffi 1.15.1 which is
incompatible.
scikit-image 0.24.0 requires imageio>=2.33, but you have imageio 2.31.1 which is
```

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

1 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

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


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

# for auto-reloading external modules
```

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

[3]:
```
def get_CIFAR10_data(num_training=49000, num_validation=1000, num_test=1000,␣
 ↪num_dev=500):
    """
    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 issue)
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,)
```

1.1 Softmax Classifier

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

[5]:
```
# 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: 2.345899
sanity check: 2.302585
```

1.2 Inline Question 1:

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

Your answer: *Fill this in*

We expect the loss to be close to -log(0.1) because of the way the softmax loss function is designed and the initial conditions of our classifier.

1. Understanding the Softmax Function:

```
* The softmax classifier outputs probabilities for each class by normalizing the raw scores (lo

* The loss for a single data point is -log(py),is the probability assigned to the correct class
```

2. Random Initialization of Weights:

```
* When we initialize the weight matrix  with small random values, the raw scores (logits) for

* As a result, the softmax probabilities for all classes become roughly equal. For  classes, t
```

3. Loss with Uniform Probabilities:

```
* For the CIFAR-10 dataset, we have 10 classes (  = 10),so each class has an equal probability

* Substituting   = 0.1 into the loss formula -log( ), we get -log(0.1)  2.302585.

* Therefore, we expect the average loss to be close to this value at the start.
```

4. Why It's Not Exactly $-\log(0.1)$:

```
* The actual loss might deviate slightly because:

  * The weight initialization, while random, is not perfectly symmetric.

  * The dataset might not have perfectly uniform distributions of classes in the sampled miniba
```

Thus, At initialization, the model assigns roughly equal probabilities to all classes because the weights are randomly initialized and there's no meaningful structure in the predictions yet. This leads to a softmax loss that approximates $-\log(1/\ )$, which in this case is $-\log(0.1)$ 2.302585.

[6]:
```
# 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: 0.611529 analytic: 0.611529, relative error: 9.919252e-08
numerical: 0.206527 analytic: 0.206527, relative error: 3.416237e-07
numerical: -0.563526 analytic: -0.563526, relative error: 3.992586e-08
numerical: 0.009354 analytic: 0.009354, relative error: 2.546502e-06
numerical: -2.865454 analytic: -2.865454, relative error: 6.129823e-11
numerical: -0.676505 analytic: -0.676505, relative error: 5.979998e-08
numerical: 0.250689 analytic: 0.250689, relative error: 3.165685e-08
numerical: 1.846244 analytic: 1.846244, relative error: 9.072495e-09
numerical: 1.024461 analytic: 1.024460, relative error: 1.066768e-07
numerical: 0.115710 analytic: 0.115710, relative error: 7.134728e-07
numerical: 0.339765 analytic: 0.339765, relative error: 5.692639e-08
numerical: -1.204218 analytic: -1.204218, relative error: 2.061541e-08
numerical: 0.748070 analytic: 0.748070, relative error: 3.931086e-08
numerical: -2.090191 analytic: -2.090191, relative error: 1.105953e-09
numerical: -2.541641 analytic: -2.541641, relative error: 2.202744e-09
numerical: 0.341646 analytic: 0.341646, relative error: 3.493273e-08
numerical: 1.483318 analytic: 1.483318, relative error: 4.616989e-09
numerical: -4.840106 analytic: -4.840106, relative error: 9.686271e-09
numerical: -2.702569 analytic: -2.702569, relative error: 1.283737e-08
numerical: 1.808957 analytic: 1.808957, relative error: 2.298422e-08
```

[7]:
```
# Now that we have a naive implementation of the softmax loss function and its␣
 ↪gradient,
# implement a vectorized version in softmax_loss_vectorized.
# The two versions should compute the same results, but the vectorized version␣
 ↪should be
# 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)
```

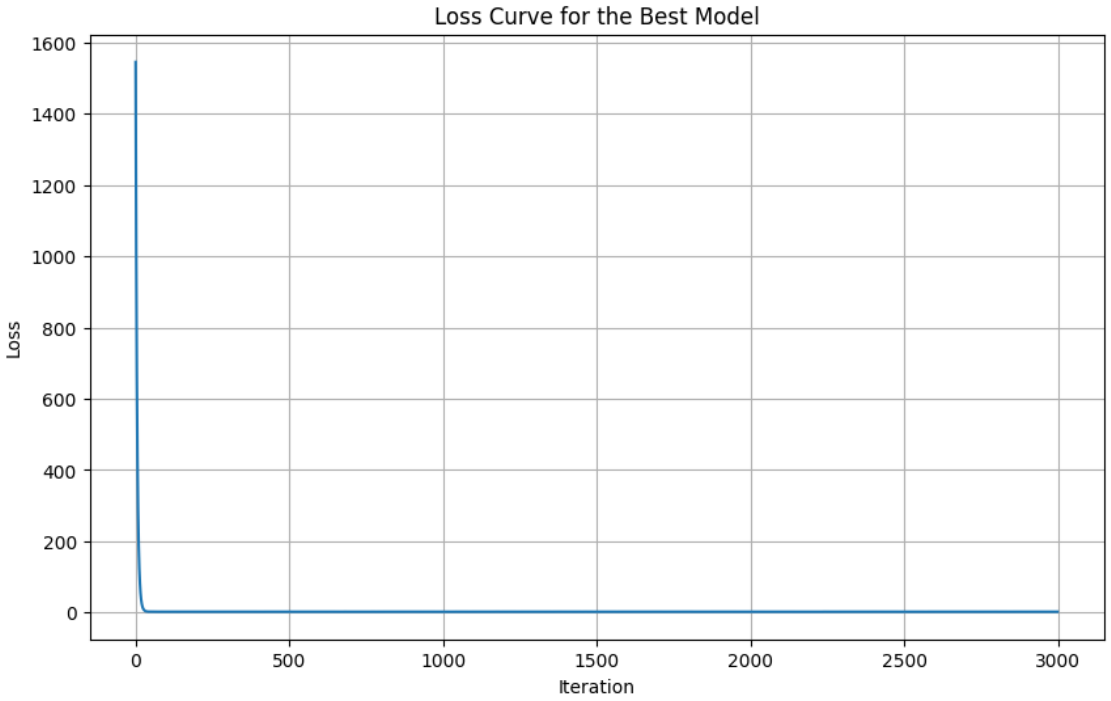
```
naive loss: 2.345899e+00 computed in 0.113384s
vectorized loss: 2.345899e+00 computed in 0.032297s
Loss difference: 0.000000
Gradient difference: 0.000000
```

[9]:
```
# 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-8, 5e-8, 1e-7, 5e-7, 1e-6]
regularization_strengths = [2e4, 2.5e4, 3e4, 4e4, 5e4]

################################################################################
# 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.                         #
################################################################################

# Number of iterations for training
num_iters = 3000

for lr in learning_rates:
    for reg in regularization_strengths:
        softmax = Softmax()
        # Train the softmax classifier
        loss_hist = softmax.train(X_train, y_train, learning_rate=lr, reg=reg,␣
 ↪num_iters=num_iters, verbose=False)

        # Evaluate training accuracy
        y_train_pred = softmax.predict(X_train)
        train_accuracy = np.mean(y_train_pred == y_train)
```

```
        # Evaluate validation accuracy
        y_val_pred = softmax.predict(X_val)
        val_accuracy = np.mean(y_val_pred == y_val)

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

        # Update the best model
        if val_accuracy > best_val:
            best_val = val_accuracy
            best_softmax = softmax



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

# Print out results.
for lr, reg in results:
    train_accuracy, val_accuracy = results[(lr, reg)]
    print(f'lr {lr:e} reg {reg:e} train accuracy: {train_accuracy:.3f} val␣
 ↪accuracy: {val_accuracy:.3f}')

print(f'Best validation accuracy achieved: {best_val:.3f}')

# Visualize the loss trends for the best model
plt.figure(figsize=(10, 6))
plt.plot(loss_hist)
plt.title('Loss Curve for the Best Model')
plt.xlabel('Iteration')
plt.ylabel('Loss')
plt.grid(True)
plt.show()

# Evaluate the best model on the test set
y_test_pred = best_softmax.predict(X_test)
test_accuracy = np.mean(y_test_pred == y_test)
print(f'Final test set accuracy: {test_accuracy:.3f}')
```

```
lr 1.000000e-08 reg 2.000000e+04 train accuracy: 0.222 val accuracy: 0.231
lr 1.000000e-08 reg 2.500000e+04 train accuracy: 0.236 val accuracy: 0.265
lr 1.000000e-08 reg 3.000000e+04 train accuracy: 0.263 val accuracy: 0.281
lr 1.000000e-08 reg 4.000000e+04 train accuracy: 0.288 val accuracy: 0.300
lr 1.000000e-08 reg 5.000000e+04 train accuracy: 0.297 val accuracy: 0.319
lr 5.000000e-08 reg 2.000000e+04 train accuracy: 0.339 val accuracy: 0.349
lr 5.000000e-08 reg 2.500000e+04 train accuracy: 0.331 val accuracy: 0.350
```

```
lr 5.000000e-08 reg 3.000000e+04 train accuracy: 0.321 val accuracy: 0.336
lr 5.000000e-08 reg 4.000000e+04 train accuracy: 0.318 val accuracy: 0.327
lr 5.000000e-08 reg 5.000000e+04 train accuracy: 0.304 val accuracy: 0.316
lr 1.000000e-07 reg 2.000000e+04 train accuracy: 0.340 val accuracy: 0.353
lr 1.000000e-07 reg 2.500000e+04 train accuracy: 0.327 val accuracy: 0.341
lr 1.000000e-07 reg 3.000000e+04 train accuracy: 0.322 val accuracy: 0.340
lr 1.000000e-07 reg 4.000000e+04 train accuracy: 0.317 val accuracy: 0.333
lr 1.000000e-07 reg 5.000000e+04 train accuracy: 0.306 val accuracy: 0.321
lr 5.000000e-07 reg 2.000000e+04 train accuracy: 0.335 val accuracy: 0.347
lr 5.000000e-07 reg 2.500000e+04 train accuracy: 0.333 val accuracy: 0.352
lr 5.000000e-07 reg 3.000000e+04 train accuracy: 0.321 val accuracy: 0.321
lr 5.000000e-07 reg 4.000000e+04 train accuracy: 0.303 val accuracy: 0.315
lr 5.000000e-07 reg 5.000000e+04 train accuracy: 0.304 val accuracy: 0.325
lr 1.000000e-06 reg 2.000000e+04 train accuracy: 0.325 val accuracy: 0.324
lr 1.000000e-06 reg 2.500000e+04 train accuracy: 0.319 val accuracy: 0.321
lr 1.000000e-06 reg 3.000000e+04 train accuracy: 0.309 val accuracy: 0.324
lr 1.000000e-06 reg 4.000000e+04 train accuracy: 0.295 val accuracy: 0.307
lr 1.000000e-06 reg 5.000000e+04 train accuracy: 0.275 val accuracy: 0.285
Best validation accuracy achieved: 0.353
```




```
Final test set accuracy: 0.352
```

[10]:
```
# 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: 0.352000
```

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: The statement is true

Your explanation:

The Structured SVM (Support Vector Machine) loss is based on the concept of margins. It encourages the correct class to have a score that is higher than the scores of all other classes by a margin of at least 1 (or a delta value).

- For any given data point, if the difference between the correct class score and the incorrect class scores satisfies the margin condition, then the loss for that data point is zero, and it does not contribute to the overall loss.
- Adding a new data point to the training set that already satisfies the margin condition will not change the SVM loss. Such a point is considered "non-supporting" because it lies far from the decision boundary and does not influence the model. This is why SVM is considered sparse—only a subset of data points (support vectors) directly affects the model.

The Softmax classifier works differently. The Softmax loss encourages the correct class to have a higher score than all other classes, but instead of relying on a margin, it computes the probability of each class using the softmax function.

- For the Softmax loss, every data point contributes to the overall loss, regardless of how confidently it is classified. Even if a data point is correctly classified with high confidence, is very close to 1, it still contributes a small, non-zero loss value.
- Adding a new data point to the training set will always affect the Softmax loss because the loss depends on the probabilities, which in turn depend on all the scores. Even if the model is already confident in its predictions, the presence of an additional data point will still influence the gradient update and change the overall loss slightly.

Thus, statement is true because for the SVM loss, it is possible to add a data point that does not affect the loss if it is correctly classified with a sufficient margin. However, for the Softmax loss, every data point affects the loss, even if it is correctly classified with high confidence, due to the way probabilities are computed and contribute to the overall loss.

[13]:
```
# 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', 'truck']
```

```
for i in range(10):
    plt.subplot(2, 5, i + 1)

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