

two_layer_net

December 12, 2024

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

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

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

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

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

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Mounted at /content/drive
/content/drive/My Drive/cs6353/assignments/assignment2/cs6353/datasets
--2024-12-06 18:59:19-- http://www.cs.toronto.edu/~kriz/cifar-10-python.tar.gz
Resolving www.cs.toronto.edu (www.cs.toronto.edu)... 128.100.3.30
Connecting to www.cs.toronto.edu (www.cs.toronto.edu)|128.100.3.30|:80...
connected.
HTTP request sent, awaiting response... 200 OK
Length: 170498071 (163M) [application/x-gzip]
Saving to: 'cifar-10-python.tar.gz'
```

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cifar-10-python.tar 100%[=====>] 162.60M 28.5MB/s in 6.4s
```

2024-12-06 18:59:26 (25.5 MB/s) - 'cifar-10-python.tar.gz' saved
[170498071/170498071]

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

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151.0/151.0

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

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

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

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

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

59.1/59.1 kB

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Collecting seaborn==0.12.2 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 85))
  Downloading seaborn-0.12.2-py3-none-any.whl.metadata (5.4 kB)
Collecting Send2Trash==1.8.2 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 86))
  Downloading Send2Trash-1.8.2-py3-none-any.whl.metadata (4.0 kB)
Requirement already satisfied: six==1.16.0 in /usr/local/lib/python3.10/dist-
packages (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 87)) (1.16.0)
Collecting sniffio==1.3.0 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 88))
  Downloading sniffio-1.3.0-py3-none-any.whl.metadata (3.6 kB)
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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 90))
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Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 91))
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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.manynlinux1_x86_64.man
ylinux_2_17_x86_64.manynlinux2014_x86_64.whl.metadata (2.5 kB)
Collecting traitlets==5.9.0 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 94))
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Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 95))
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Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 96))
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Collecting urllib3==2.0.4 (from -r /content/drive/My
Drive/cs6353/assignments/assignment2//colab_requirements.txt (line 97))
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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)
        66.4/66.4 kB
4.9 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
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Downloading Babel-2.12.1-py3-none-any.whl (10.1 MB)
        10.1/10.1 MB
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Downloading beautifulsoup4-4.12.2-py3-none-any.whl (142 kB)
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441.8/441.8 kB
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ylinux2014_x86_64.whl (201 kB)
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Downloading comm-0.1.4-py3-none-any.whl (6.6 kB)
Downloading
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kB)
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Downloading
debugpy-1.6.7.post1-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.whl
(3.0 MB)
3.0/3.0 MB
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Downloading fastjsonschema-2.18.0-py3-none-any.whl (23 kB)
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MB)
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Downloading idna-3.4-py3-none-any.whl (61 kB)
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313.2/313.2 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)
83.4/83.4 kB

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Downloading jupyter_events-0.7.0-py3-none-any.whl (18 kB)
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Downloading notebook_shim-0.2.3-py3-none-any.whl (13 kB)

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59.0/59.0 kB
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118.7/118.7 kB
9.4 MB/s eta 0:00:00
Downloading Pygments-2.16.1-py3-none-any.whl (1.2 MB)
1.2/1.2 MB
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Downloading pyparsing-3.0.9-py3-none-any.whl (98 kB)
98.3/98.3 kB
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Downloading python_json_logger-2.0.7-py3-none-any.whl (8.1 kB)
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PyYAML-6.0.1-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.whl (705 kB)
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Downloading rfc3986_validator-0.1.1-py2.py3-none-any.whl (4.2 kB)
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rpds_py-0.9.2-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.whl (1.2
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Downloading stack_data-0.6.2-py3-none-any.whl (24 kB)
Downloading terminado-0.17.1-py3-none-any.whl (17 kB)
Downloading tinycss2-1.2.1-py3-none-any.whl (21 kB)
Downloading traitlets-5.9.0-py3-none-any.whl (117 kB)

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123.9/123.9 kB
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Downloading webcolors-1.13-py3-none-any.whl (14 kB)
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57.0/57.0 kB
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17.1/17.1 MB
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12.1/12.1 MB
58.5 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
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Installing collected packages: wcwidth, pytz, pure-eval, json5, fastjsonschema, executing, appnope, websocket-client, webcolors, urllib3, uri-template, tzdata, traitlets, tornado, tinycss2, soupsieve, sniffio, Send2Trash, rpds-py, rfc3986-validator, rfc3339-validator, PyYAML, python-json-logger, pyparsing, Pygments, pycparser, prompt-toolkit, prometheus-client, platformdirs, Pillow, pexpect, parso, pandocfilters, packaging, overrides, numpy, nest-asyncio, mistune, MarkupSafe, kiwisolver, jupyterlab-pygments, jsonpointer, idna, fqdn, fonttools, debugpy, cyclo, charset-normalizer, certifi, bleach, Babel, attrs, async-lru, asttokens, terminado, stack-data, scipy, requests, referencing, pandas, matplotlib-inline, jupyter_core, Jinja2, jedi, imageio, contourpy, comm, cffi, beautifulsoup4, arrow, matplotlib, jupyter_server_terminals, jupyter_client, jsonschema-specifications, isoduration, seaborn, jsonschema, nbformat, nbclient, jupyter-events, nbconvert, jupyter_server, notebook_shim, jupyterlab_server, jupyter-lsp, jupyterlab

Attempting uninstall: wcwidth

Found existing installation: wcwidth 0.2.13

Uninstalling wcwidth-0.2.13:

Successfully uninstalled wcwidth-0.2.13

Attempting uninstall: pytz

Found existing installation: pytz 2024.2

Uninstalling pytz-2024.2:

Successfully uninstalled pytz-2024.2

Attempting uninstall: fastjsonschema

Found existing installation: fastjsonschema 2.21.1

Uninstalling fastjsonschema-2.21.1:

Successfully uninstalled fastjsonschema-2.21.1

Attempting uninstall: websocket-client

Found existing installation: websocket-client 1.8.0

Uninstalling websocket-client-1.8.0:

Successfully uninstalled websocket-client-1.8.0

Attempting uninstall: webcolors

Found existing installation: webcolors 24.11.1

Uninstalling webcolors-24.11.1:

Successfully uninstalled webcolors-24.11.1

Attempting uninstall: urllib3

Found existing installation: urllib3 2.2.3

Uninstalling urllib3-2.2.3:

Successfully uninstalled urllib3-2.2.3

Attempting uninstall: tzdata

Found existing installation: tzdata 2024.2

Uninstalling tzdata-2024.2:

Successfully uninstalled tzdata-2024.2

Attempting uninstall: traitlets

Found existing installation: traitlets 5.7.1

Uninstalling traitlets-5.7.1:

Successfully uninstalled traitlets-5.7.1

Attempting uninstall: tornado

Found existing installation: tornado 6.3.3

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

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Uninstalling platformdirs-4.3.6:
 Successfully uninstalled platformdirs-4.3.6
Attempting uninstall: Pillow
 Found existing installation: pillow 11.0.0
 Uninstalling pillow-11.0.0:
 Successfully uninstalled pillow-11.0.0
Attempting uninstall: pexpect
 Found existing installation: pexpect 4.9.0
 Uninstalling pexpect-4.9.0:
 Successfully uninstalled pexpect-4.9.0
Attempting uninstall: parso
 Found existing installation: parso 0.8.4
 Uninstalling parso-0.8.4:
 Successfully uninstalled parso-0.8.4
Attempting uninstall: pandocfilters
 Found existing installation: pandocfilters 1.5.1
 Uninstalling pandocfilters-1.5.1:
 Successfully uninstalled pandocfilters-1.5.1
Attempting uninstall: packaging
 Found existing installation: packaging 24.2
 Uninstalling packaging-24.2:
 Successfully uninstalled packaging-24.2
Attempting uninstall: numpy
 Found existing installation: numpy 1.26.4
 Uninstalling numpy-1.26.4:
 Successfully uninstalled numpy-1.26.4
Attempting uninstall: nest-asyncio
 Found existing installation: nest-asyncio 1.6.0
 Uninstalling nest-asyncio-1.6.0:
 Successfully uninstalled nest-asyncio-1.6.0
Attempting uninstall: mistune
 Found existing installation: mistune 3.0.2
 Uninstalling mistune-3.0.2:
 Successfully uninstalled mistune-3.0.2
Attempting uninstall: MarkupSafe
 Found existing installation: MarkupSafe 3.0.2
 Uninstalling MarkupSafe-3.0.2:
 Successfully uninstalled MarkupSafe-3.0.2
Attempting uninstall: kiwisolver
 Found existing installation: kiwisolver 1.4.7
 Uninstalling kiwisolver-1.4.7:
 Successfully uninstalled kiwisolver-1.4.7
Attempting uninstall: jupyterlab-pygments
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Attempting uninstall: jsonpointer
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Attempting uninstall: idna
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Attempting uninstall: fonttools
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 Successfully uninstalled fonttools-4.55.1
Attempting uninstall: debugpy
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Attempting uninstall: cycler
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Attempting uninstall: charset-normalizer
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Attempting uninstall: certifi
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Attempting uninstall: bleach
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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
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 Successfully uninstalled terminado-0.18.1
Attempting uninstall: scipy
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Attempting uninstall: matplotlib-inline
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Attempting uninstall: jupyter_core
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Attempting uninstall: Jinja2
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Attempting uninstall: imageio
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 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:
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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
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Attempting uninstall: jsonschema
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    Successfully uninstalled jsonschema-4.23.0
Attempting uninstall: nbformat
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Attempting uninstall: jupyter_server
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  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.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

1 Implementing a Neural Network

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

```
[ ]: # A bit of setup

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

from cs6353.classifiers.neural_net import TwoLayerNet

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

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

def rel_error(x, y):
    """ returns relative error """
```

```
return np.max(np.abs(x - y) / (np.maximum(1e-8, np.abs(x) + np.abs(y))))
```

The autoreload extension is already loaded. To reload it, use:

```
%reload_ext autoreload
```

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

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

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

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

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

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

2 Forward pass: compute scores

Open the file `cs6353/classifiers/neural_net.py` and look at the method `TwoLayerNet.loss`. This function is very similar to the loss functions you have written for the SVM and Softmax exercises: It takes the data and weights and computes the class scores, the loss, and the gradients on the parameters.

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

```
[ ]: scores = net.loss(X)
      print('Your scores:')
      print(scores)
      print()
      print('correct scores:')
      correct_scores = np.asarray([
          [-0.81233741, -1.27654624, -0.70335995],
```

```

[-0.17129677, -1.18803311, -0.47310444],
[-0.51590475, -1.01354314, -0.8504215 ],
[-0.15419291, -0.48629638, -0.52901952],
[-0.00618733, -0.12435261, -0.15226949]])
print(correct_scores)
print()

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

```

Your scores:

```

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

```

correct scores:

```

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

```

Difference between your scores and correct scores:

3.6802720745909845e-08

3 Forward pass: compute loss

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

```

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

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

```

Difference between your loss and correct loss:

1.7985612998927536e-13

4 Backward pass

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

```
[ ]: from cs6353.gradient_check import eval_numerical_gradient

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

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

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

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

5 Train the network

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

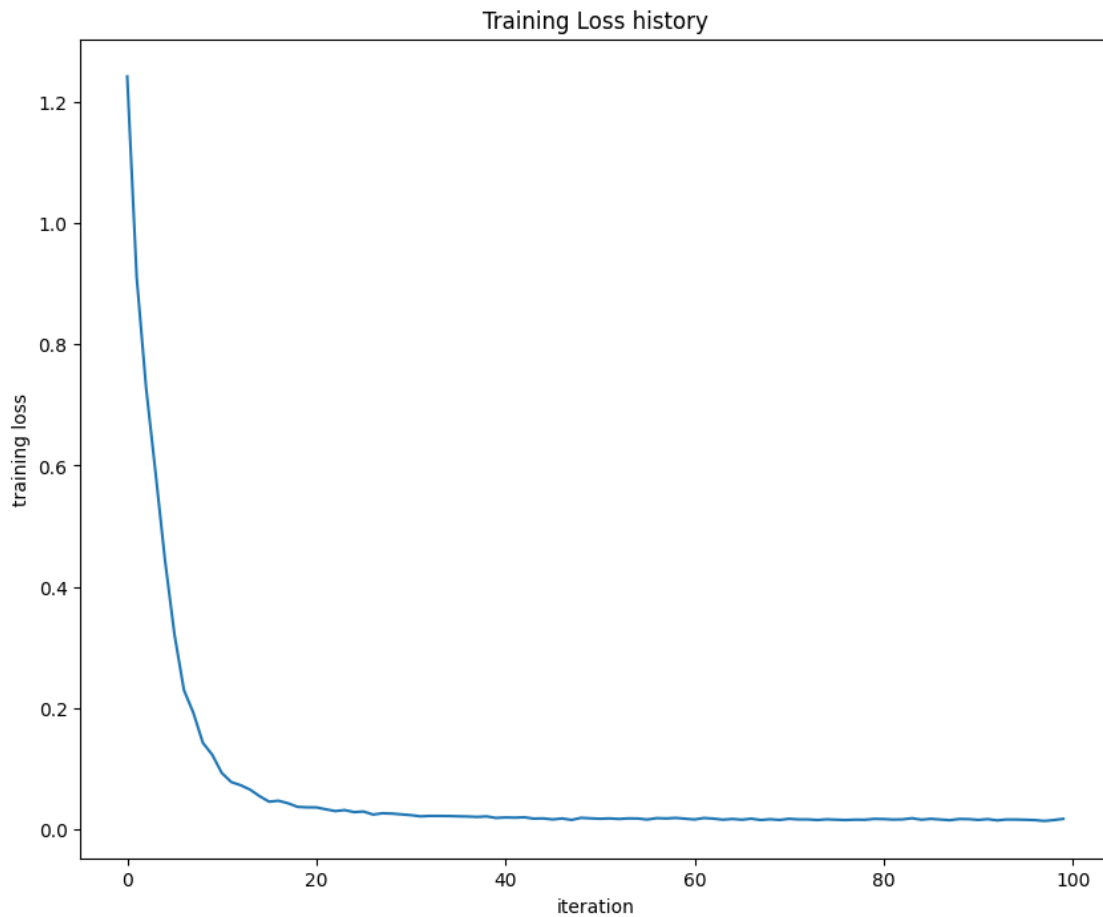
Once you have implemented the method, run the code below to train a two-layer network on toy data. You should achieve a training loss less than 0.2.

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

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

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


Final training loss: 0.017149607938732093



6 Load the data

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

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

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

```

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

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

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

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

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

# Cleaning up variables to prevent loading data multiple times (which may cause
↳memory 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 = get_CIFAR10_data()
print('Train data shape: ', X_train.shape)
print('Train labels shape: ', y_train.shape)
print('Validation data shape: ', X_val.shape)
print('Validation labels shape: ', y_val.shape)
print('Test data shape: ', X_test.shape)
print('Test labels shape: ', y_test.shape)

```

```

Train data shape: (49000, 3072)
Train labels shape: (49000,)

```

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

7 Train a network

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

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

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

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

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

8 Debug the training

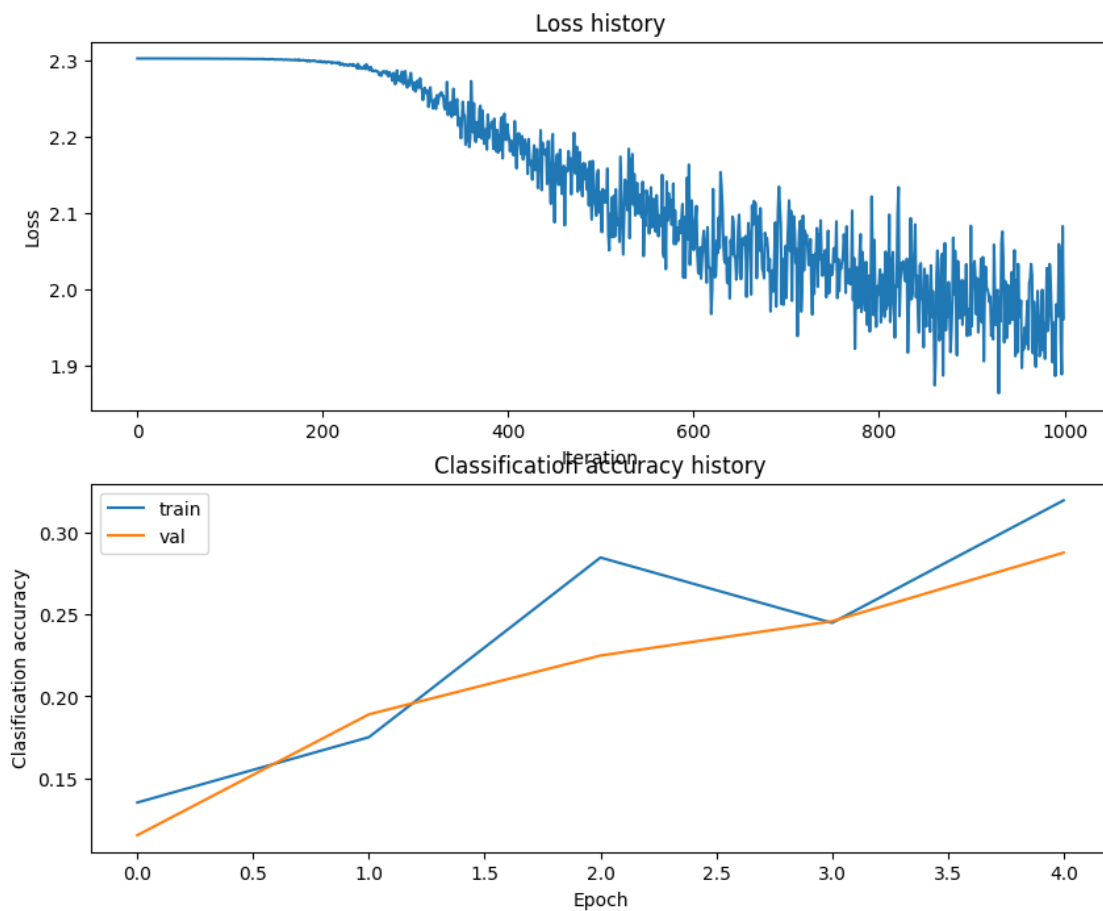
With the default parameters we provided above, you should get a validation accuracy of about 0.29 on the validation set. This isn't very good.

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

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

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

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

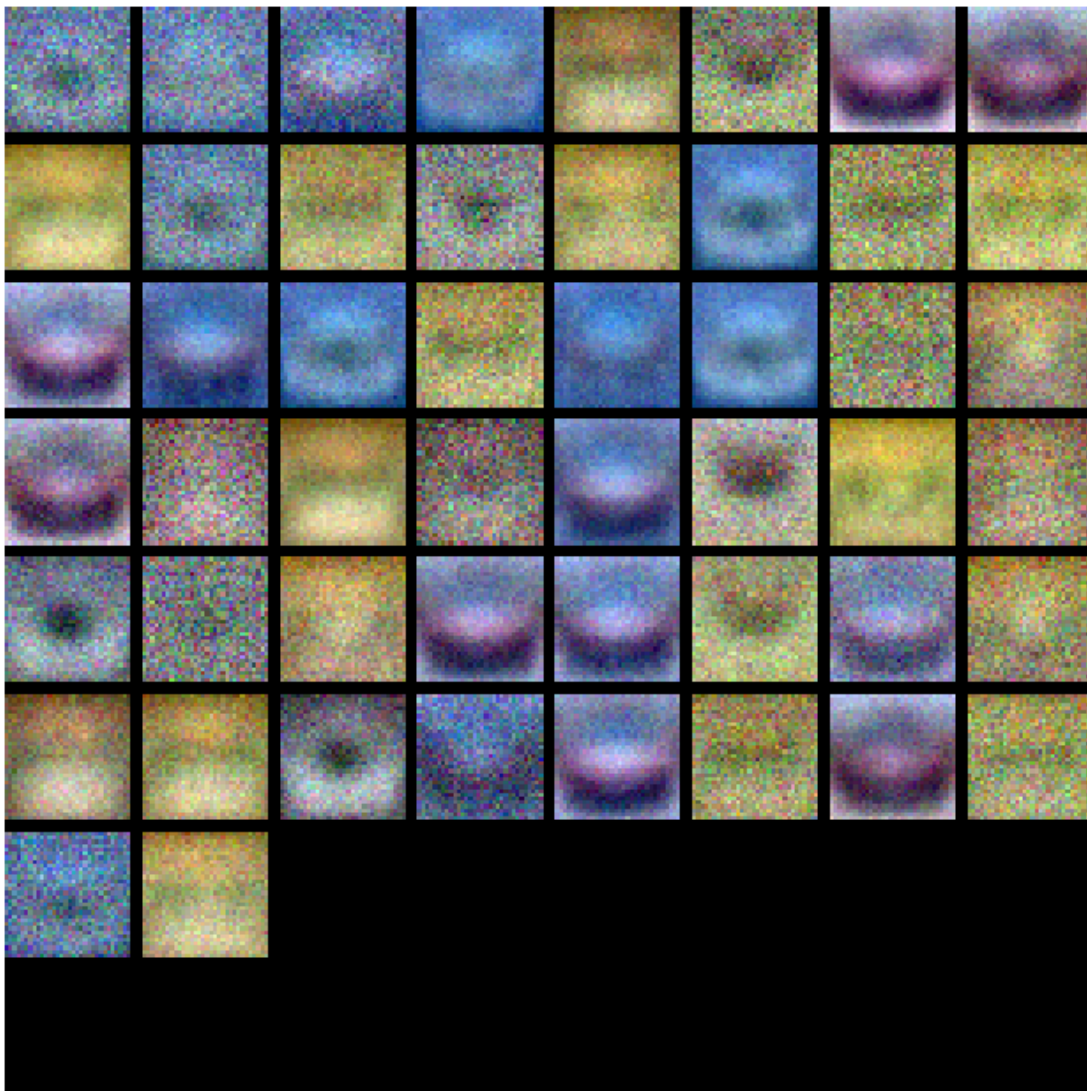


```
[ ]: from cs6353.vis_utils import visualize_grid
```

```
# Visualize the weights of the network

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

show_net_weights(net)
```



9 Tune your hyperparameters

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

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

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

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

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

#####
# TODO: Tune hyperparameters using the validation set. Store your best trained
  ↪#
# model in best_net.
  ↪#
#
  ↪#
# To help debug your network, it may help to use visualizations similar to the
  ↪#
# ones we used above; these visualizations will have significant qualitative
  ↪#
# differences from the ones we saw above for the poorly tuned network.
  ↪#
#
  ↪#
# Tweaking hyperparameters by hand can be fun, but you might find it useful to
  ↪#
# write code to sweep through possible combinations of hyperparameters
  ↪#
# automatically like we did on the previous exercises.
  ↪#
#####
```

```

best_val_acc = 0
best_stats = None # To store statistics of the best network
hidden_layer_sizes = [50, 100, 200] # Try different hidden layer sizes
learning_rates = [1e-4, 5e-4, 1e-3] # Try different learning rates
regularization_strengths = [0.1, 0.25, 0.5, 1.0] # Regularization strengths
num_iters = 2000 # Increase iterations for better convergence

# Loop through all combinations of hyperparameters
for hidden_size in hidden_layer_sizes:
    for learning_rate in learning_rates:
        for reg in regularization_strengths:
            print(f"Training with hidden_size={hidden_size}, \u
            ↪learning_rate={learning_rate}, reg={reg}")

            # Initialize a new network
            net = TwoLayerNet(input_size, hidden_size, num_classes)

            # Train the network
            stats = net.train(
                X_train, y_train, X_val, y_val,
                num_iters=num_iters, batch_size=200,
                learning_rate=learning_rate, learning_rate_decay=0.95,
                reg=reg, verbose=False
            )

            # Predict validation accuracy
            val_acc = (net.predict(X_val) == y_val).mean()
            print(f"Validation accuracy: {val_acc}")

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

# Print the best validation accuracy achieved
print(f"Best validation accuracy achieved: {best_val_acc}")

# Visualize the loss history and classification accuracy for the best network
plt.subplot(2, 1, 1)
plt.plot(best_stats['loss_history'])
plt.title('Loss history (Best Network)')
plt.xlabel('Iteration')
plt.ylabel('Loss')

plt.subplot(2, 1, 2)
plt.plot(best_stats['train_acc_history'], label='train')

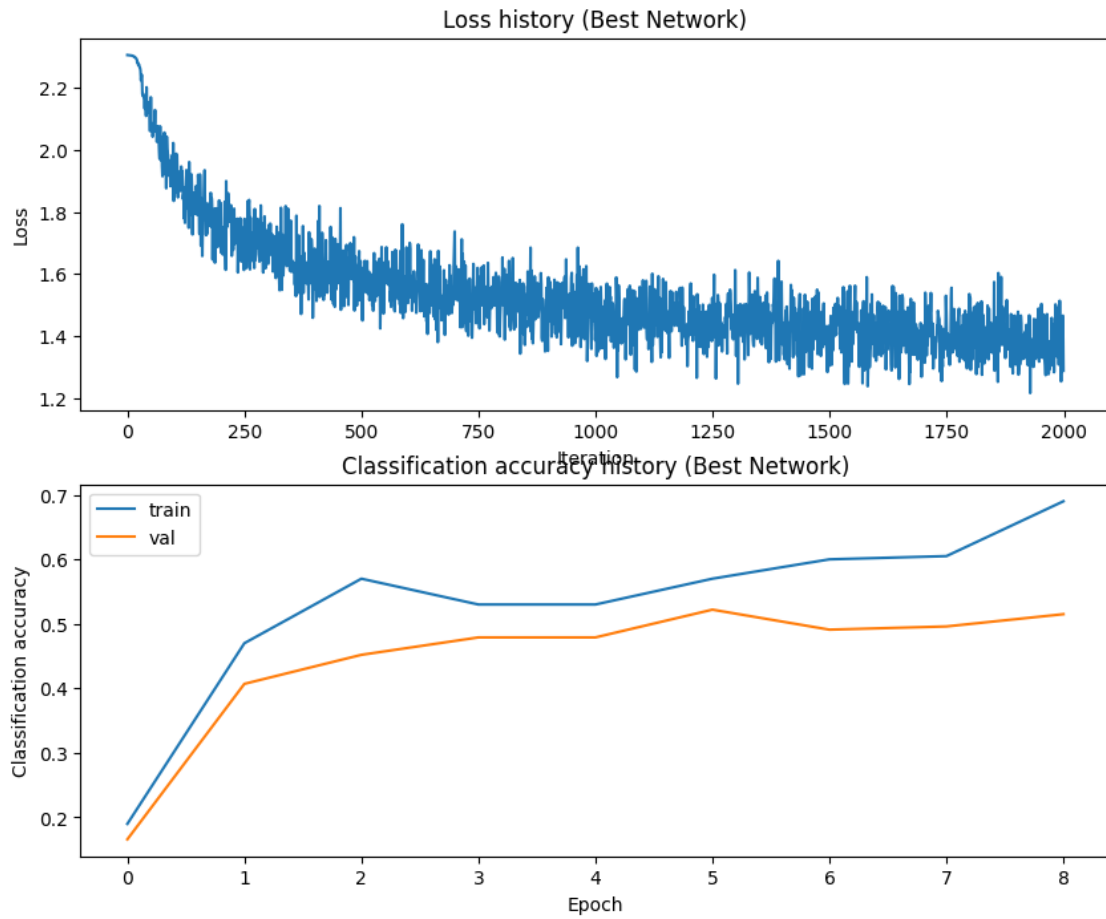
```

```
plt.plot(best_stats['val_acc_history'], label='val')
plt.title('Classification accuracy history (Best Network)')
plt.xlabel('Epoch')
plt.ylabel('Classification accuracy')
plt.legend()
plt.show()
```

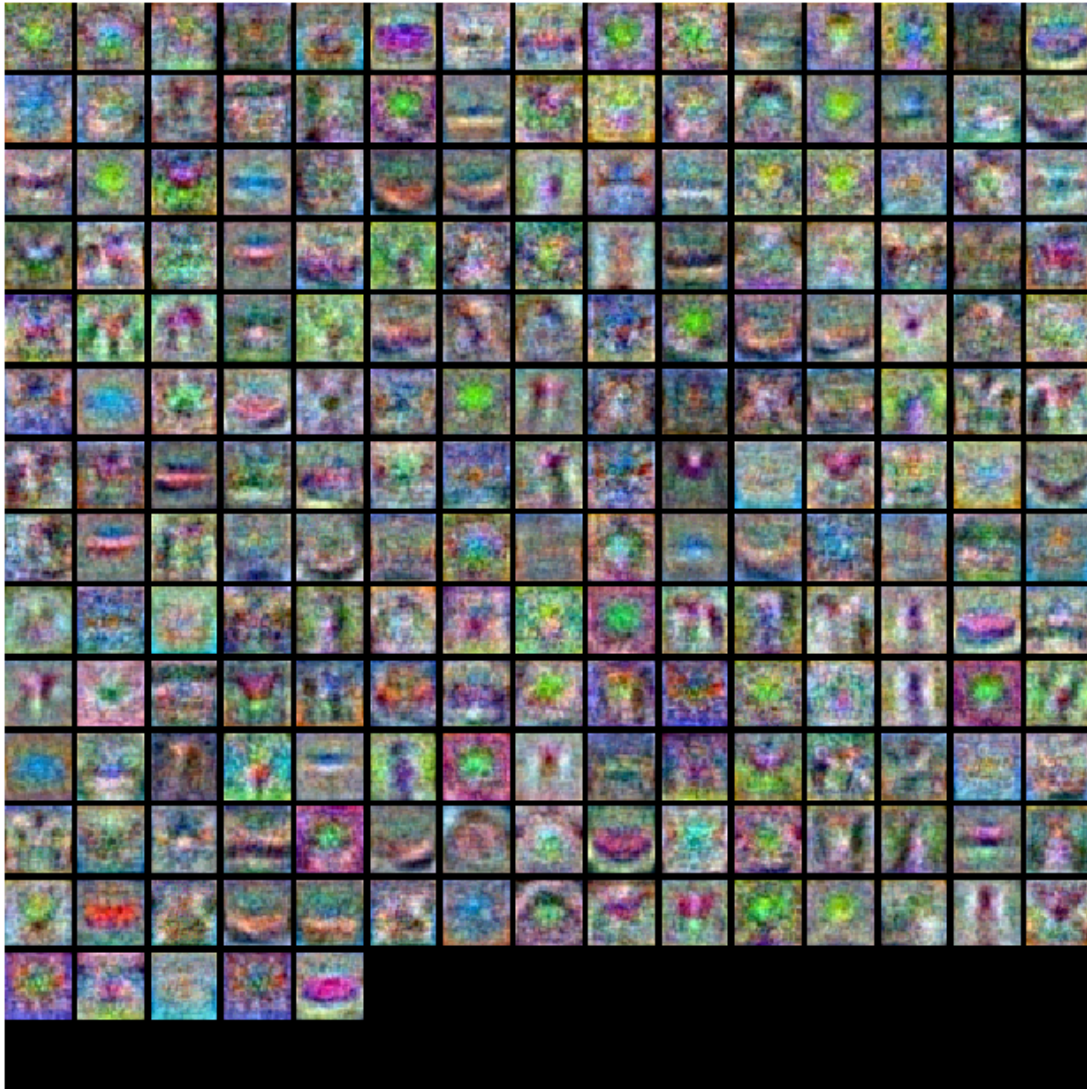
```
#####
#                                     END OF YOUR CODE                                     #
#                                     #
#####
```

```
Training with hidden_size=50, learning_rate=0.0001, reg=0.1
Validation accuracy: 0.355
Training with hidden_size=50, learning_rate=0.0001, reg=0.25
Validation accuracy: 0.361
Training with hidden_size=50, learning_rate=0.0001, reg=0.5
Validation accuracy: 0.358
Training with hidden_size=50, learning_rate=0.0001, reg=1.0
Validation accuracy: 0.353
Training with hidden_size=50, learning_rate=0.0005, reg=0.1
Validation accuracy: 0.479
Training with hidden_size=50, learning_rate=0.0005, reg=0.25
Validation accuracy: 0.475
Training with hidden_size=50, learning_rate=0.0005, reg=0.5
Validation accuracy: 0.483
Training with hidden_size=50, learning_rate=0.0005, reg=1.0
Validation accuracy: 0.47
Training with hidden_size=50, learning_rate=0.001, reg=0.1
Validation accuracy: 0.494
Training with hidden_size=50, learning_rate=0.001, reg=0.25
Validation accuracy: 0.481
Training with hidden_size=50, learning_rate=0.001, reg=0.5
Validation accuracy: 0.482
Training with hidden_size=50, learning_rate=0.001, reg=1.0
Validation accuracy: 0.475
Training with hidden_size=100, learning_rate=0.0001, reg=0.1
Validation accuracy: 0.373
Training with hidden_size=100, learning_rate=0.0001, reg=0.25
Validation accuracy: 0.362
Training with hidden_size=100, learning_rate=0.0001, reg=0.5
Validation accuracy: 0.37
Training with hidden_size=100, learning_rate=0.0001, reg=1.0
Validation accuracy: 0.362
Training with hidden_size=100, learning_rate=0.0005, reg=0.1
```


Validation accuracy: 0.475
Training with hidden_size=100, learning_rate=0.0005, reg=0.25
Validation accuracy: 0.483
Training with hidden_size=100, learning_rate=0.0005, reg=0.5
Validation accuracy: 0.472
Training with hidden_size=100, learning_rate=0.0005, reg=1.0
Validation accuracy: 0.467
Training with hidden_size=100, learning_rate=0.001, reg=0.1
Validation accuracy: 0.504
Training with hidden_size=100, learning_rate=0.001, reg=0.25
Validation accuracy: 0.501
Training with hidden_size=100, learning_rate=0.001, reg=0.5
Validation accuracy: 0.498
Training with hidden_size=100, learning_rate=0.001, reg=1.0
Validation accuracy: 0.485
Training with hidden_size=200, learning_rate=0.0001, reg=0.1
Validation accuracy: 0.37
Training with hidden_size=200, learning_rate=0.0001, reg=0.25
Validation accuracy: 0.369
Training with hidden_size=200, learning_rate=0.0001, reg=0.5
Validation accuracy: 0.369
Training with hidden_size=200, learning_rate=0.0001, reg=1.0
Validation accuracy: 0.364
Training with hidden_size=200, learning_rate=0.0005, reg=0.1
Validation accuracy: 0.495
Training with hidden_size=200, learning_rate=0.0005, reg=0.25
Validation accuracy: 0.479
Training with hidden_size=200, learning_rate=0.0005, reg=0.5
Validation accuracy: 0.485
Training with hidden_size=200, learning_rate=0.0005, reg=1.0
Validation accuracy: 0.467
Training with hidden_size=200, learning_rate=0.001, reg=0.1
Validation accuracy: 0.501
Training with hidden_size=200, learning_rate=0.001, reg=0.25
Validation accuracy: 0.508
Training with hidden_size=200, learning_rate=0.001, reg=0.5
Validation accuracy: 0.508
Training with hidden_size=200, learning_rate=0.001, reg=1.0
Validation accuracy: 0.495
Best validation accuracy achieved: 0.508



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



10 Run on the test set

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

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

Test accuracy: 0.51

Inline Question

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

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

Your answer:

The correct options are:

- 1. Train on a larger dataset.
- 3. Increase the regularization strength.

Your explanation:

The gap between training and testing accuracy is commonly referred to as overfitting, which occurs when the model learns the training data too well, including its noise and specific details, but fails to generalize to unseen data. Let's analyze the options in detail:

- 1. Train on a larger dataset:

A larger dataset provides more diverse examples for the model to learn from, reducing the risk of overfitting. With more training data, the model is exposed to a broader range of patterns and features, which improves its ability to generalize to unseen data.

Overfitting often happens when the model is “memorizing” the limited training examples instead of learning general patterns. By adding more data, the model is forced to learn underlying trends rather than relying on specific details.

- 2. Increase the regularization strength:

Regularization penalizes large weights in the model, effectively reducing the complexity of the model. This forces the model to focus on the most important features, discouraging it from overfitting to the training data.

L2 regularization (weight decay) and dropout are common techniques to reduce overfitting. By increasing the regularization strength, the model is less likely to “memorize” the training set and more likely to generalize to new examples.