

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

# TODO: Enter the foldername in your Drive where you have saved the unzipped
# assignment folder, e.g. 'cs6353/assignments/assignment2/'
FOLDERNAME = 'CS6353/Assignments/assignment2/assignment2/'
assert FOLDERNAME is not None, "[!] Enter the foldername."

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

# This downloads the CIFAR-10 dataset to your Drive
# if it doesn't already exist.
%cd /content/drive/My\ Drive/$FOLDERNAME/cs6353/datasets/
!bash get_datasets.sh
%cd /content/drive/My\ Drive/$FOLDERNAME

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

Mounted at /content/drive  
/content/drive/My Drive/CS6353/Assignments/assignment2/assignment2/cs6353/datasets  
--2024-09-29 20:36:13-- http://www.cs.toronto.edu/~kriz/cifar-10-python.tar.gz  
Resolving www.cs.toronto.edu (www.cs.toronto.edu)... 128.100.3.30  
Connecting to www.cs.toronto.edu (www.cs.toronto.edu)|128.100.3.30|:80... connected.  
HTTP request sent, awaiting response... 200 OK  
Length: 170498071 (163M) [application/x-gzip]  
Saving to: 'cifar-10-python.tar.gz'

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

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

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/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/assignment2//colab\_requirements.txt (line 1)) (3.7.1)  
Collecting appnope==0.1.3 (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/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/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/assignment2//colab\_requirements.txt (line 4)) (21.2.0)  
Collecting arrow==1.2.3 (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/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/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/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/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/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/assignment2//colab\_requirements.txt (line 10)) (0.2.0)  
Collecting beautifulsoup4==4.12.2 (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//colab\_requirements.txt (line 11))  
Downloading beautifulsoup4-4.12.2-py3-none-any.whl.metadata (3.6 kB)  
Collecting bleach==6.0.0 (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//colab\_requirements.txt (line 12))  
Downloading bleach-6.0.0-py3-none-any.whl.metadata (29 kB)

Collecting certifi==2023.7.22 (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/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/assignment2//colab\_requirements.txt (line 14))  
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 Collecting charset-normalizer==3.2.0 (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//colab\_requirements.txt (line 15))  
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 Collecting comm==0.1.4 (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//colab\_requirements.txt (line 16))  
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 Collecting contourpy==1.1.0 (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//colab\_requirements.txt (line 17))  
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 Collecting cycler==0.11.0 (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/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/assignment2//colab\_requirements.txt (line 19))  
 Downloading debugpy-1.6.7.post1-cp310-cp310-manylinux\_2\_17\_x86\_64.manylinux2014\_x86\_64.whl.metadata (1.1 kB)  
 Requirement already satisfied: decorator<=5.0 in /usr/local/lib/python3.10/dist-packages (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/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/assignment2//colab\_requirements.txt (line 21)) (0.7.1)  
 Collecting executing==1.2.0 (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/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/assignment2//colab\_requirements.txt (line 23))  
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 Collecting fonttools==4.42.1 (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//colab\_requirements.txt (line 24))  
 Downloading fonttools-4.42.1-cp310-cp310-manylinux\_2\_17\_x86\_64.manylinux2014\_x86\_64.whl.metadata (150 kB)  


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 151.0/151.0 kB 5.1 MB/s eta 0:00:00  
 Collecting fqdn==1.5.1 (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//colab\_requirements.txt (line 25))  
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 Collecting idna==3.4 (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//colab\_requirements.txt (line 26))  
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 Collecting imageio==2.31.1 (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/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/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/assignment2//colab\_requirements.txt (line 29)) (7.34.0)  
 Collecting isoduration==20.11.0 (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/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/assignment2//colab\_requirements.txt (line 31))  
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Collecting Jinja2==3.1.2 (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/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/assignment2//colab\_requirements.txt (line 33))  
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Collecting jsonpointer==2.4 (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/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/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/assignment2//colab\_requirements.txt (line 36))  
 Downloading jsonschema\_specifications-2023.7.1-py3-none-any.whl.metadata (2.8 kB)  
Collecting jupyter-events==0.7.0 (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//colab\_requirements.txt (line 37))  
 Downloading jupyter\_events-0.7.0-py3-none-any.whl.metadata (5.5 kB)  
Collecting jupyter-lsp==2.2.0 (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/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/assignment2//colab\_requirements.txt (line 39)) (6.1.12)  
Collecting jupyter\_core==5.3.1 (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//colab\_requirements.txt (line 40))  
 Downloading jupyter\_core-5.3.1-py3-none-any.whl.metadata (3.4 kB)  
Collecting jupyter\_server==2.7.2 (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//colab\_requirements.txt (line 41))  
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Collecting jupyter\_server\_terminals==0.4.4 (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//colab\_requirements.txt (line 42))  
 Downloading jupyter\_server\_terminals-0.4.4-py3-none-any.whl.metadata (6.3 kB)  
Collecting jupyterlab==4.0.5 (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/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/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/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/assignment2//colab\_requirements.txt (line 46))  
 Downloading kiwisolver-1.4.5-cp310-cp310-manylinux\_2\_12\_x86\_64.manylinux2010\_x86\_64.whl.metadata (6.4 kB)  
Collecting MarkupSafe==2.1.3 (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//colab\_requirements.txt (line 47))  
 Downloading MarkupSafe-2.1.3-cp310-cp310-manylinux\_2\_17\_x86\_64.manylinux2014\_x86\_64.whl.metadata (3.0 kB)  
Collecting matplotlib==3.7.2 (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//colab\_requirements.txt (line 48))  
 Downloading matplotlib-3.7.2-cp310-cp310-manylinux\_2\_17\_x86\_64.manylinux2014\_x86\_64.whl.metadata (5.6 kB)  
Collecting matplotlib-inline==0.1.6 (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//colab\_requirements.txt (line 49))  
 Downloading matplotlib\_inline-0.1.6-py3-none-any.whl.metadata (2.8 kB)

Collecting mistune==3.0.1 (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/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/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/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/assignment2//colab\_requirements.txt (line 53))  
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 Collecting nest-asyncio==1.5.7 (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/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/assignment2//colab\_requirements.txt (line 55))  
 Downloading notebook\_shim-0.2.3-py3-none-any.whl.metadata (4.0 kB)  
 Collecting numpy<1.24,>=1.22 (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/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/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/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/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/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/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/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/assignment2//colab\_requirements.txt (line 63)) (0.7.5)  
 Collecting Pillow==10.0.0 (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/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/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/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/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/assignment2//colab\_requirements.txt (line 68)) (5.9.5)  
 Requirement already satisfied: ptyprocess==0.7.0 in /usr/local/lib/python3.10/dist-pa

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ckages (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//colab_requirements.txt (line 69)) (0.7.0)
Collecting pure-eval==0.2.2 (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//colab_requirements.txt (line 70))
  Downloading pure_eval-0.2.2-py3-none-any.whl.metadata (6.2 kB)
Collecting pycparser==2.21 (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/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/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/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/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/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/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/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/assignment2//colab_requirements.txt (line 78)) (24.0.1)
Collecting referencing==0.30.2 (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/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/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/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/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/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/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 4.2 MB/s eta 0:00:00
Collecting seaborn==0.12.2 (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/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/assignment2//colab_requirements.txt (line 86))
  Downloading Send2Trash-1.8.2-py3-none-any.whl.metadata (4.0 kB)
Requirement already satisfied: six==1.16.0 in /usr/local/lib/python3.10/dist-packages (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//colab_requirements.txt (line 87)) (1.16.0)

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Collecting sniffio==1.3.0 (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//colab\_requirements.txt (line 88))  
 Downloading sniffio-1.3.0-py3-none-any.whl.metadata (3.6 kB)  
 Collecting soupsieve==2.4.1 (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//colab\_requirements.txt (line 89))  
 Downloading soupsieve-2.4.1-py3-none-any.whl.metadata (4.7 kB)  
 Collecting stack-data==0.6.2 (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//colab\_requirements.txt (line 90))  
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 Collecting terminado==0.17.1 (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//colab\_requirements.txt (line 91))  
 Downloading terminado-0.17.1-py3-none-any.whl.metadata (5.9 kB)  
 Collecting tinycss2==1.2.1 (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//colab\_requirements.txt (line 92))  
 Downloading tinycss2-1.2.1-py3-none-any.whl.metadata (3.0 kB)  
 Collecting tornado<=6.3.2 (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//colab\_requirements.txt (line 93))  
 Downloading tornado-6.3.2-cp38-abi3-manylinux\_2\_5\_x86\_64.manylinux1\_x86\_64.manylinux\_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/assignment2//colab\_requirements.txt (line 94))  
 Downloading traitlets-5.9.0-py3-none-any.whl.metadata (10 kB)  
 Collecting tzdata==2023.3 (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//colab\_requirements.txt (line 95))  
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 Collecting urllib3==2.0.4 (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/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/assignment2//colab\_requirements.txt (line 98))  
 Downloading wcwidth-0.2.6-py2.py3-none-any.whl.metadata (11 kB)  
 Collecting webcolors==1.13 (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//colab\_requirements.txt (line 99))  
 Downloading webcolors-1.13-py3-none-any.whl.metadata (2.6 kB)  
 Requirement already satisfied: webencodings==0.5.1 in /usr/local/lib/python3.10/dist-packages (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//colab\_requirements.txt (line 100)) (0.5.1)  
 Collecting websocket-client==1.6.2 (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/assignment2//colab\_requirements.txt (line 101))  
 Downloading websocket\_client-1.6.2-py3-none-any.whl.metadata (7.5 kB)  
 Requirement already satisfied: exceptiongroup in /usr/local/lib/python3.10/dist-packages (from anyio==3.7.1->-r /content/drive/My Drive/CS6353/Assignments/assignment2/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/assignment2//colab\_requirements.txt (line 7)) (4.12.2)  
 Collecting jupyter\_client<8.0 (from -r /content/drive/My Drive/CS6353/Assignments/assignment2/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/assignment2//colab\_requirements.txt (line 43)) (2.0.1)  
 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/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/assignment



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2/assignment2//colab_requirements.txt (line 29)) (71.0.4)
Requirement already satisfied: entrypoints in /usr/local/lib/python3.10/dist-packages
(from jupyter_client<8.0->-r /content/drive/My Drive/CS6353/Assignments/assignment2/a
ssignment2//colab_requirements.txt (line 39)) (0.4)
Downloading appnope-0.1.3-py2.py3-none-any.whl (4.4 kB)
Downloading arrow-1.2.3-py3-none-any.whl (66 kB)
_____ 66.4/66.4 kB 5.0 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)
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41 kB)
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x86_64.whl (201 kB)
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Downloading contourpy-1.1.0-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.wh
l (300 kB)
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4.whl (3.0 MB)
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hl (4.5 MB)
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Downloading jupyter_server-2.7.2-py3-none-any.whl (375 kB)
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Downloading jupyterlab-4.0.5-py3-none-any.whl (9.2 MB)
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Downloading jupyterlab_pygments-0.2.2-py2.py3-none-any.whl (21 kB)
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hl (1.6 MB)
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hl (11.6 MB)
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Downloading prompt_toolkit-3.0.39-py3-none-any.whl (385 kB)
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Downloading pure_eval-0.2.2-py3-none-any.whl (11 kB)
Downloading pycparser-2.21-py2.py3-none-any.whl (118 kB)
_____ 118.7/118.7 kB 8.5 MB/s eta 0:00:00
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Downloading sniffio-1.3.0-py3-none-any.whl (10 kB)
Downloading soupsieve-2.4.1-py3-none-any.whl (36 kB)
Downloading stack_data-0.6.2-py3-none-any.whl (24 kB)
Downloading terminado-0.17.1-py3-none-any.whl (17 kB)
Downloading tinycss2-1.2.1-py3-none-any.whl (21 kB)
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Downloading webcolors-1.13-py3-none-any.whl (14 kB)
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Downloading jupyter_client-7.4.9-py3-none-any.whl (133 kB)
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Downloading numpy-1.23.5-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.whl
(17.1 MB)
17.1/17.1 MB 75.8 MB/s eta 0:00:00
Downloading pandas-1.5.3-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.whl
(12.1 MB)
12.1/12.1 MB 90.8 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 25.6 MB/s eta 0:00:00
Installing collected packages: wcwidth, pytz, pure-eval, json5, fastjsonschema, execu
ting, appnope, websocket-client, webcolors, urllib3, uri-template, tzdata, traitlets,
tornado, tinycss2, soupsieve, sniffio, Send2Trash, rpds-py, rfc3986-validator, rfc333
9-validator, PyYAML, python-json-logger, pyparsing, Pygments, pycparser, prompt-toolk
it, prometheus-client, platformdirs, Pillow, pexpect, parso, pandocfilters, packagin
g, overrides, numpy, nest-asyncio, mistune, MarkupSafe, kiwisolver, jupyterlab-pygmen
ts, jsonpointer, idna, fqdn, fonttools, debugpy, cyclr, charset-normalizer, certifi,
bleach, Babel, attrs, async-lru, asttokens, terminado, stack-data, scipy, requests, r
eferencing, pandas, matplotlib-inline, jupyter_core, Jinja2, jedi, imageio, contourp
y, comm, cffi, beautifulsoup4, arrow, matplotlib, jupyter_server_terminals, jupyter_c
lient, jsonschema-specifications, isoduration, seaborn, jsonschema, nbformat, nbclien
t, jupyter-events, nbconvert, jupyter_server, notebook_shim, jupyterlab_server, jupyte
r-lsp, jupyterlab
Attempting uninstall: wcwidth
Found existing installation: wcwidth 0.2.13
Uninstalling wcwidth-0.2.13:
Successfully uninstalled wcwidth-0.2.13
Attempting uninstall: pytz
Found existing installation: pytz 2024.2
Uninstalling pytz-2024.2:
Successfully uninstalled pytz-2024.2
Attempting uninstall: fastjsonschema
Found existing installation: fastjsonschema 2.20.0
Uninstalling fastjsonschema-2.20.0:
Successfully uninstalled fastjsonschema-2.20.0
Attempting uninstall: websocket-client

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Found existing installation: websocket-client 1.8.0  
Uninstalling websocket-client-1.8.0:  
Successfully uninstalled websocket-client-1.8.0  
Attempting uninstall: webcolors  
Found existing installation: webcolors 24.8.0  
Uninstalling webcolors-24.8.0:  
Successfully uninstalled webcolors-24.8.0  
Attempting uninstall: urllib3  
Found existing installation: urllib3 2.2.3  
Uninstalling urllib3-2.2.3:  
Successfully uninstalled urllib3-2.2.3  
Attempting uninstall: tzdata  
Found existing installation: tzdata 2024.1  
Uninstalling tzdata-2024.1:  
Successfully uninstalled tzdata-2024.1  
Attempting uninstall: traitlets  
Found existing installation: traitlets 5.7.1  
Uninstalling traitlets-5.7.1:  
Successfully uninstalled traitlets-5.7.1  
Attempting uninstall: tornado  
Found existing installation: tornado 6.3.3  
Uninstalling tornado-6.3.3:  
Successfully uninstalled tornado-6.3.3  
Attempting uninstall: tinycss2  
Found existing installation: tinycss2 1.3.0  
Uninstalling tinycss2-1.3.0:  
Successfully uninstalled tinycss2-1.3.0  
Attempting uninstall: soupsieve  
Found existing installation: soupsieve 2.6  
Uninstalling soupsieve-2.6:  
Successfully uninstalled soupsieve-2.6  
Attempting uninstall: sniffio  
Found existing installation: sniffio 1.3.1  
Uninstalling sniffio-1.3.1:  
Successfully uninstalled sniffio-1.3.1  
Attempting uninstall: Send2Trash  
Found existing installation: Send2Trash 1.8.3  
Uninstalling Send2Trash-1.8.3:  
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Attempting uninstall: rpds-py  
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Uninstalling rpds-py-0.20.0:  
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Attempting uninstall: PyYAML  
Found existing installation: PyYAML 6.0.2  
Uninstalling PyYAML-6.0.2:  
Successfully uninstalled PyYAML-6.0.2  
Attempting uninstall: pyparsing  
Found existing installation: pyparsing 3.1.4  
Uninstalling pyparsing-3.1.4:  
Successfully uninstalled pyparsing-3.1.4  
Attempting uninstall: Pygments  
Found existing installation: Pygments 2.18.0  
Uninstalling Pygments-2.18.0:  
Successfully uninstalled Pygments-2.18.0  
Attempting uninstall: pycparser  
Found existing installation: pycparser 2.22  
Uninstalling pycparser-2.22:  
Successfully uninstalled pycparser-2.22  
Attempting uninstall: prompt-toolkit

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Found existing installation: prompt_toolkit 3.0.47
Uninstalling prompt_toolkit-3.0.47:
  Successfully uninstalled prompt_toolkit-3.0.47
Attempting uninstall: prometheus-client
Found existing installation: prometheus_client 0.21.0
Uninstalling prometheus_client-0.21.0:
  Successfully uninstalled prometheus_client-0.21.0
Attempting uninstall: platformdirs
Found existing installation: platformdirs 4.3.6
Uninstalling platformdirs-4.3.6:
  Successfully uninstalled platformdirs-4.3.6
Attempting uninstall: Pillow
Found existing installation: pillow 10.4.0
Uninstalling pillow-10.4.0:
  Successfully uninstalled pillow-10.4.0
Attempting uninstall: pexpect
Found existing installation: pexpect 4.9.0
Uninstalling pexpect-4.9.0:
  Successfully uninstalled pexpect-4.9.0
Attempting uninstall: parso
Found existing installation: parso 0.8.4
Uninstalling parso-0.8.4:
  Successfully uninstalled parso-0.8.4
Attempting uninstall: pandocfilters
Found existing installation: pandocfilters 1.5.1
Uninstalling pandocfilters-1.5.1:
  Successfully uninstalled pandocfilters-1.5.1
Attempting uninstall: packaging
Found existing installation: packaging 24.1
Uninstalling packaging-24.1:
  Successfully uninstalled packaging-24.1
Attempting uninstall: numpy
Found existing installation: numpy 1.26.4
Uninstalling numpy-1.26.4:
  Successfully uninstalled numpy-1.26.4
Attempting uninstall: nest-asyncio
Found existing installation: nest-asyncio 1.6.0
Uninstalling nest-asyncio-1.6.0:
  Successfully uninstalled nest-asyncio-1.6.0
Attempting uninstall: mistune
Found existing installation: mistune 0.8.4
Uninstalling mistune-0.8.4:
  Successfully uninstalled mistune-0.8.4
Attempting uninstall: MarkupSafe
Found existing installation: MarkupSafe 2.1.5
Uninstalling MarkupSafe-2.1.5:
  Successfully uninstalled MarkupSafe-2.1.5
Attempting uninstall: kiwisolver
Found existing installation: kiwisolver 1.4.7
Uninstalling kiwisolver-1.4.7:
  Successfully uninstalled kiwisolver-1.4.7
Attempting uninstall: jupyterlab-pygments
Found existing installation: jupyterlab_pygments 0.3.0
Uninstalling jupyterlab_pygments-0.3.0:
  Successfully uninstalled jupyterlab_pygments-0.3.0
Attempting uninstall: idna
Found existing installation: idna 3.10
Uninstalling idna-3.10:
  Successfully uninstalled idna-3.10
Attempting uninstall: fonttools
```

Found existing installation: fonttools 4.53.1  
Uninstalling fonttools-4.53.1:  
    Successfully uninstalled fonttools-4.53.1  
Attempting uninstall: debugpy  
Found existing installation: debugpy 1.6.6  
Uninstalling debugpy-1.6.6:  
    Successfully uninstalled debugpy-1.6.6  
Attempting uninstall: cycler  
Found existing installation: cycler 0.12.1  
Uninstalling cycler-0.12.1:  
    Successfully uninstalled cycler-0.12.1  
Attempting uninstall: charset-normalizer  
Found existing installation: charset-normalizer 3.3.2  
Uninstalling charset-normalizer-3.3.2:  
    Successfully uninstalled charset-normalizer-3.3.2  
Attempting uninstall: certifi  
Found existing installation: certifi 2024.8.30  
Uninstalling certifi-2024.8.30:  
    Successfully uninstalled certifi-2024.8.30  
Attempting uninstall: bleach  
Found existing installation: bleach 6.1.0  
Uninstalling bleach-6.1.0:  
    Successfully uninstalled bleach-6.1.0  
Attempting uninstall: Babel  
Found existing installation: babel 2.16.0  
Uninstalling babel-2.16.0:  
    Successfully uninstalled babel-2.16.0  
Attempting uninstall: attrs  
Found existing installation: attrs 24.2.0  
Uninstalling attrs-24.2.0:  
    Successfully uninstalled attrs-24.2.0  
Attempting uninstall: terminado  
Found existing installation: terminado 0.18.1  
Uninstalling terminado-0.18.1:  
    Successfully uninstalled terminado-0.18.1  
Attempting uninstall: scipy  
Found existing installation: scipy 1.13.1  
Uninstalling scipy-1.13.1:  
    Successfully uninstalled scipy-1.13.1  
Attempting uninstall: requests  
Found existing installation: requests 2.32.3  
Uninstalling requests-2.32.3:  
    Successfully uninstalled requests-2.32.3  
Attempting uninstall: referencing  
Found existing installation: referencing 0.35.1  
Uninstalling referencing-0.35.1:  
    Successfully uninstalled referencing-0.35.1  
Attempting uninstall: pandas  
Found existing installation: pandas 2.1.4  
Uninstalling pandas-2.1.4:  
    Successfully uninstalled pandas-2.1.4  
Attempting uninstall: matplotlib-inline  
Found existing installation: matplotlib-inline 0.1.7  
Uninstalling matplotlib-inline-0.1.7:  
    Successfully uninstalled matplotlib-inline-0.1.7  
Attempting uninstall: jupyter\_core  
Found existing installation: jupyter\_core 5.7.2  
Uninstalling jupyter\_core-5.7.2:  
    Successfully uninstalled jupyter\_core-5.7.2  
Attempting uninstall: Jinja2

```
Found existing installation: Jinja2 3.1.4
Uninstalling Jinja2-3.1.4:
  Successfully uninstalled Jinja2-3.1.4
Attempting uninstall: imageio
Found existing installation: imageio 2.35.1
Uninstalling imageio-2.35.1:
  Successfully uninstalled imageio-2.35.1
Attempting uninstall: contourpy
Found existing installation: contourpy 1.3.0
Uninstalling contourpy-1.3.0:
  Successfully uninstalled contourpy-1.3.0
Attempting uninstall: cffi
Found existing installation: cffi 1.17.1
Uninstalling cffi-1.17.1:
  Successfully uninstalled cffi-1.17.1
Attempting uninstall: beautifulsoup4
Found existing installation: beautifulsoup4 4.12.3
Uninstalling beautifulsoup4-4.12.3:
  Successfully uninstalled beautifulsoup4-4.12.3
Attempting uninstall: matplotlib
Found existing installation: matplotlib 3.7.1
Uninstalling matplotlib-3.7.1:
  Successfully uninstalled matplotlib-3.7.1
Attempting uninstall: jupyter_client
Found existing installation: jupyter-client 6.1.12
Uninstalling jupyter-client-6.1.12:
  Successfully uninstalled jupyter-client-6.1.12
Attempting uninstall: jsonschema-specifications
Found existing installation: jsonschema-specifications 2023.12.1
Uninstalling jsonschema-specifications-2023.12.1:
  Successfully uninstalled jsonschema-specifications-2023.12.1
Attempting uninstall: seaborn
Found existing installation: seaborn 0.13.1
Uninstalling seaborn-0.13.1:
  Successfully uninstalled seaborn-0.13.1
Attempting uninstall: jsonschema
Found existing installation: jsonschema 4.23.0
Uninstalling jsonschema-4.23.0:
  Successfully uninstalled jsonschema-4.23.0
Attempting uninstall: nbformat
Found existing installation: nbformat 5.10.4
Uninstalling nbformat-5.10.4:
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Attempting uninstall: nbclient
Found existing installation: nbclient 0.10.0
Uninstalling nbclient-0.10.0:
  Successfully uninstalled nbclient-0.10.0
Attempting uninstall: nbconvert
Found existing installation: nbconvert 6.5.4
Uninstalling nbconvert-6.5.4:
  Successfully uninstalled nbconvert-6.5.4
Attempting uninstall: jupyter_server
Found existing installation: jupyter-server 1.24.0
Uninstalling jupyter-server-1.24.0:
  Successfully uninstalled jupyter-server-1.24.0
Attempting uninstall: notebook_shim
Found existing installation: notebook_shim 0.2.4
Uninstalling notebook_shim-0.2.4:
  Successfully uninstalled notebook_shim-0.2.4
```

ERROR: pip's dependency resolver does not currently take into account all the package

s that are installed. This behaviour is the source of the following dependency conflicts.

albucore 0.0.16 requires numpy>=1.24, but you have numpy 1.23.5 which is incompatible.

alumentations 1.4.15 requires numpy>=1.24.4, but you have numpy 1.23.5 which is incompatible.

bigframes 1.18.0 requires numpy>=1.24.0, but you have numpy 1.23.5 which is incompatible.

bokeh 3.4.3 requires contourpy>=1.2, but you have contourpy 1.1.0 which is incompatible.

chex 0.1.86 requires numpy>=1.24.1, but you have numpy 1.23.5 which is incompatible.

cudf-cu12 24.4.1 requires pandas<2.2.2dev0,>=2.0, but you have pandas 1.5.3 which is incompatible.

google-colab 1.0.0 requires pandas==2.1.4, but you have pandas 1.5.3 which is 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.

mizani 0.11.4 requires pandas>=2.1.0, but you have pandas 1.5.3 which is incompatible.

pandas-stubs 2.1.4.231227 requires numpy>=1.26.0; python\_version < "3.13", but you have numpy 1.23.5 which is incompatible.

plotnine 0.13.6 requires pandas<3.0.0,>=2.1.0, but you have pandas 1.5.3 which is incompatible.

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

xarray 2024.9.0 requires numpy>=1.24, but you have numpy 1.23.5 which is incompatible.

xarray 2024.9.0 requires pandas>=2.1, but you have pandas 1.5.3 which is incompatible.

Successfully installed Babel-2.12.1 Jinja2-3.1.2 MarkupSafe-2.1.3 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 asynclru-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 cycycler-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

## Multiclass Support Vector Machine exercise

Complete and hand in this completed worksheet (including its outputs and any supporting code outside of the worksheet) with your assignment submission. For more details see the [assignments page](#) on the course website.



In this exercise you will:

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

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

# This is a bit of magic to make matplotlib figures appear inline in the
# notebook rather than in a new window.
%matplotlib inline
plt.rcParams['figure.figsize'] = (10.0, 8.0) # set default size of plots
plt.rcParams['image.interpolation'] = 'nearest'
plt.rcParams['image.cmap'] = 'gray'

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

## CIFAR-10 Data Loading and Preprocessing

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

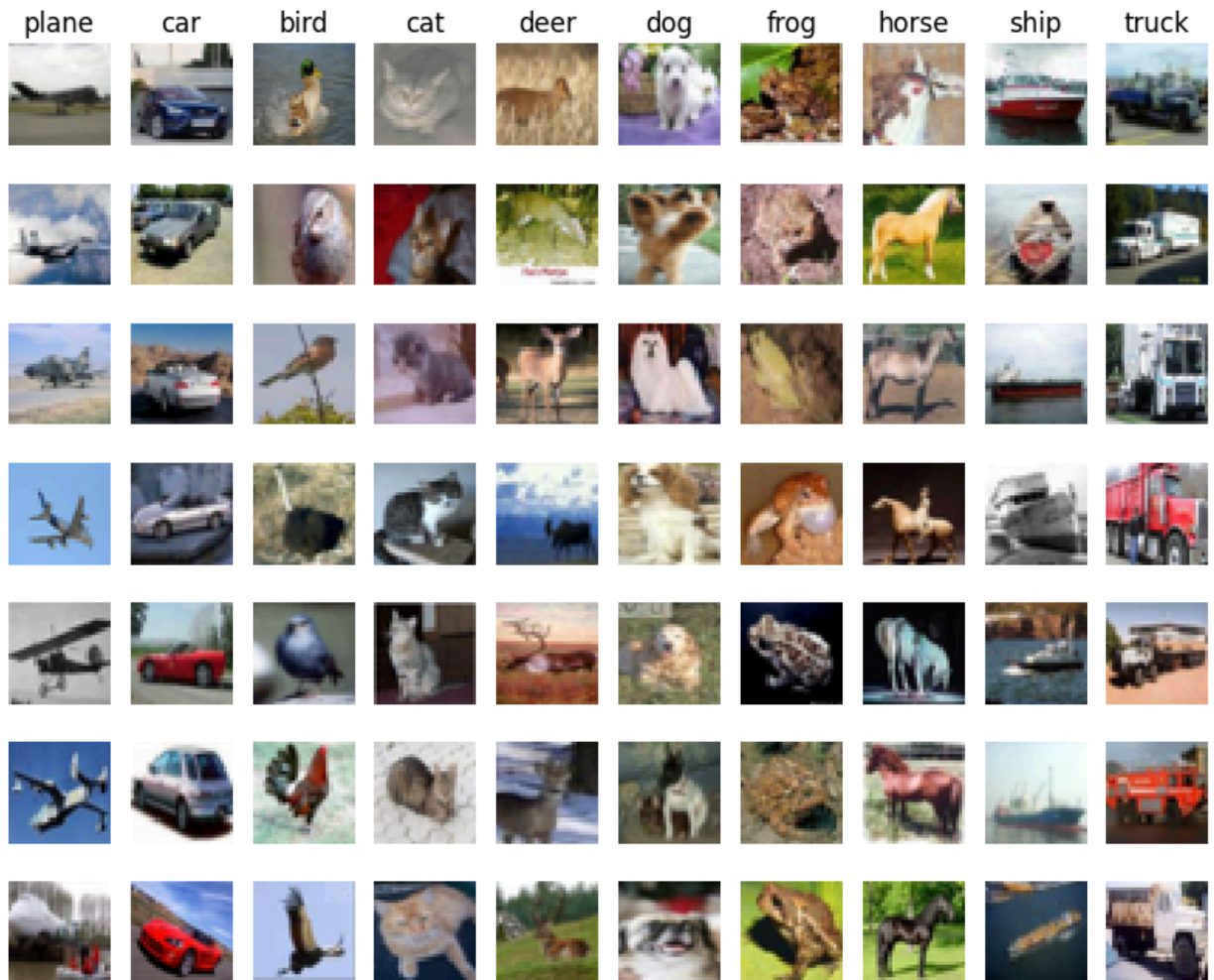
# Cleaning up variables to prevent loading data multiple times (which may cause memory
try:
    del X_train, y_train
    del X_test, y_test
    print('Clear previously loaded data.')
except:
    pass

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

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

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

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



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

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

```

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

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

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

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

print('Train data shape: ', X_train.shape)
print('Train labels shape: ', y_train.shape)
print('Validation data shape: ', X_val.shape)
print('Validation labels shape: ', y_val.shape)
print('Test data shape: ', X_test.shape)
print('Test labels shape: ', y_test.shape)

```

```

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

```

```

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

```

```

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

```

```

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

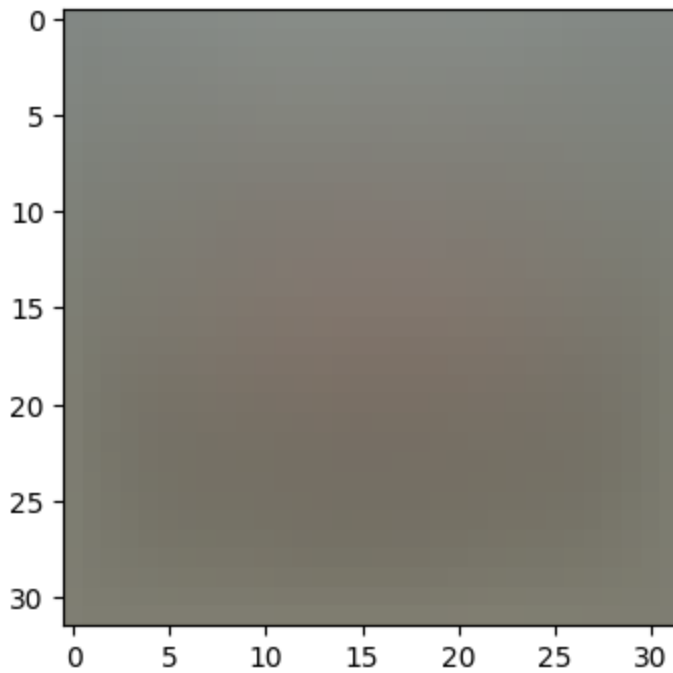
```

```

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

```

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



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

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

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

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

## SVM Classifier

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

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

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

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

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

```

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

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

```

The `grad` returned from the function above is right now all zero. Derive and implement the gradient for the SVM cost function and implement it inline inside the function

`svm_loss_naive`. You will find it helpful to interleave your new code inside the existing function.

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

```

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

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

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

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

```

```

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

```

## Inline Question 1:

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

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

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

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

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

```

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

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

```

```

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

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

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

```

```

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

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

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

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

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

```

## Stochastic Gradient Descent

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

```

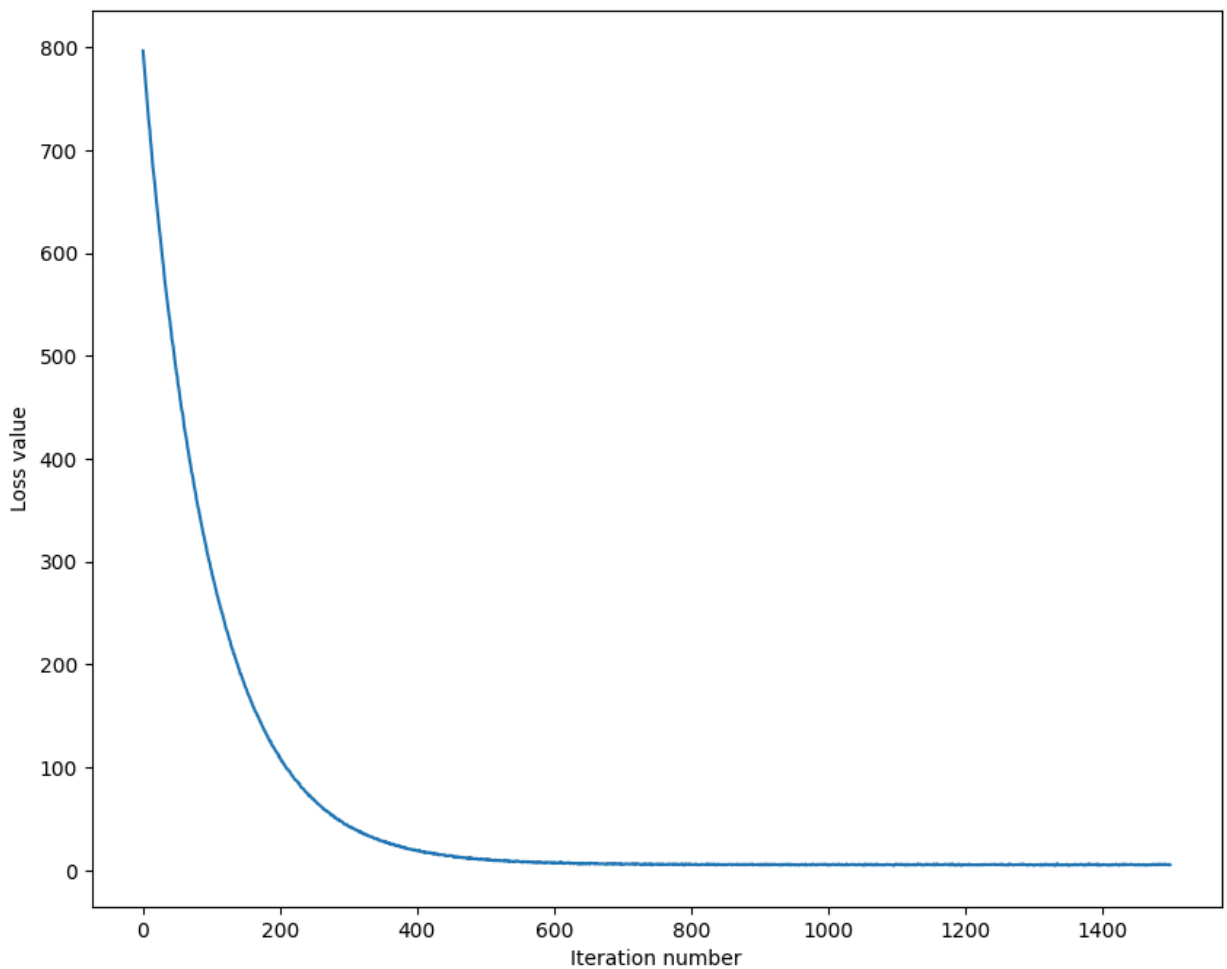
In [ ]: # In the file linear_classifier.py, implement SGD in the function
# LinearClassifier.train() and then run it with the code below.
from cs6353.classifiers import LinearSVM
svm = LinearSVM()
tic = time.time()
loss_hist = svm.train(X_train, y_train, learning_rate=1e-7, reg=2.5e4,
              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

```



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

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



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

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

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

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

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

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

        svm = LinearSVM()

        svm.train(X_train, y_train, learning_rate=lr, reg=reg, num_iters=1500, verbose=0)

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

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

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

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

        if y_val_accuracy > best_val:
            best_val = y_val_accuracy
            best_svm = svm

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

```
# Print out results.  
for lr, reg in sorted(results):  
    train_accuracy, val_accuracy = results[(lr, reg)]  
    print('lr %e reg %e train accuracy: %f val accuracy: %f' % (  
        lr, reg, train_accuracy, val_accuracy))  
  
print('best validation accuracy achieved during cross-validation: %f' % best_val)
```

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

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

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

```

iteration 0 / 1500: loss 175.468803
iteration 100 / 1500: loss 357.794190
iteration 200 / 1500: loss 261.610384
iteration 300 / 1500: loss 323.961122
iteration 400 / 1500: loss 236.804339
iteration 500 / 1500: loss 292.767227
iteration 600 / 1500: loss 338.246575
iteration 700 / 1500: loss 226.032447
iteration 800 / 1500: loss 299.913841
iteration 900 / 1500: loss 254.660160
iteration 1000 / 1500: loss 319.197245
iteration 1100 / 1500: loss 337.491635
iteration 1200 / 1500: loss 316.946059
iteration 1300 / 1500: loss 255.065476
iteration 1400 / 1500: loss 273.845585
iteration 0 / 1500: loss 794.020799
iteration 100 / 1500: loss 394760373444917569637606845452629573632.000000
iteration 200 / 1500: loss 6525072812573031292100673454664614464879456863556933790485
4949036761808896.000000
iteration 300 / 1500: loss 1078542277124495292016946587597207966718228388067316388335
3989456808185081499303733577127478046744740840341504.000000
iteration 400 / 1500: loss 1782744004485959901551228896455347888968974849861193021152
1987021846815679408570247155771735372325175882804807919132831712186340592330991720202
24.000000
iteration 500 / 1500: loss 2946733060853192242890543862612089291321853746624695376106
2412609312620855504400711067216409436130763183441465276364765271565317015346896412717
6997496598581885987809344378900578304.000000
iteration 600 / 1500: loss 4870713748062200503837272613858407099279604761114810011338
8087691493879638662815440760993692773055000442162218708269072306470479108164989868720
498729444972260726834281796386995680700894182750610075422519243279695872.000000
iteration 700 / 1500: loss 8050899733921997218766457257436512787846768561744804495639
8125075733144238517868823952847209756578607289500952999710954857546938719016050737394
8915980234832608473572482149694748882434308222412089708792544831739724783236841706512
9093766265386819387392.000000
iteration 800 / 1500: loss 1330749246995936717245578739746150383060986894711340920334
2789863200164643954264316571324759578047980950140023201099722823605441998790483201086
2589685600589912131414892180764058785897937613362917978810498622127545132469845246026
4737245018530225430950569430595262634345460622832523280384.000000

```

```

/content/drive/MyDrive/CS6353/Assignments/assignment2/assignment2/cs6353/classifiers/
linear_svm.py:100: RuntimeWarning: overflow encountered in scalar multiply

```

```

    loss += reg * np.sum(W * W)

```

```

/usr/local/lib/python3.10/dist-packages/numpy/core/fromnumeric.py:88: RuntimeWarning:
overflow encountered in reduce

```

```

/content/drive/MyDrive/CS6353/Assignments/assignment2/assignment2/cs6353/classifiers/
linear_svm.py:100: RuntimeWarning: overflow encountered in multiply

```

```

    loss += reg * np.sum(W * W)

```



```

iteration 900 / 1500: loss inf
iteration 1000 / 1500: loss inf
iteration 1100 / 1500: loss inf
iteration 1200 / 1500: loss inf
iteration 1300 / 1500: loss inf
iteration 1400 / 1500: loss inf
iteration 0 / 1500: loss 1558.822219
iteration 100 / 1500: loss 4207798039246850533175537350026849985891957311066635763731
421068684681551426265889564213148587107320794663181729815999807488.000000
iteration 200 / 1500: loss 1086558597385951279432465208308215137742869207865414633594
6470231097929239192116128043930123319357484907821011382111736380297078929685288281354
4440572810648554778182559683387244449590057481321689025821234523991051138958670226822
38881250555199488.000000
iteration 300 / 1500: loss inf
iteration 400 / 1500: loss inf
iteration 500 / 1500: loss inf

/content/drive/MyDrive/CS6353/Assignments/assignment2/assignment2/cs6353/classifiers/
linear_svm.py:125: RuntimeWarning: overflow encountered in multiply
    dW += 2 * reg * W
/content/drive/MyDrive/CS6353/Assignments/assignment2/assignment2/cs6353/classifiers/
linear_classifier.py:70: RuntimeWarning: invalid value encountered in subtract
    self.W -= learning_rate * grad
iteration 600 / 1500: loss nan
iteration 700 / 1500: loss nan
iteration 800 / 1500: loss nan
iteration 900 / 1500: loss nan
iteration 1000 / 1500: loss nan
iteration 1100 / 1500: loss nan
iteration 1200 / 1500: loss nan
iteration 1300 / 1500: loss nan
iteration 1400 / 1500: loss nan
iteration 0 / 1500: loss 3071.075695
iteration 100 / 1500: loss 2182133309946366599253484069681885190785452080302820461479
7202861682346491760762762456234455162260005124946570008000177952981352557009769576134
2850588122872372114047619043797859518559655959724032.000000
iteration 200 / 1500: loss inf
iteration 300 / 1500: loss inf

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

```

```

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

```

```

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

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

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

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

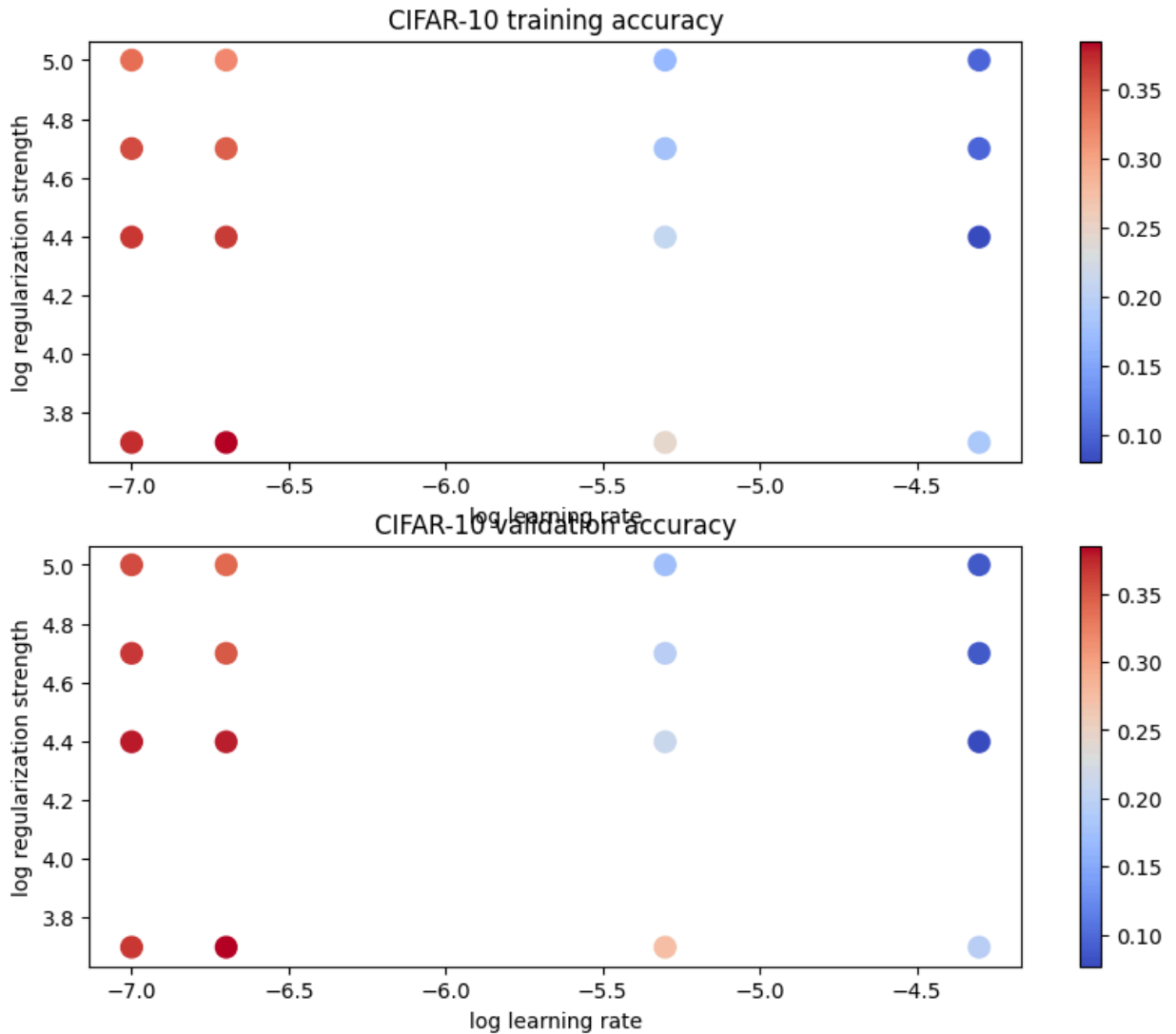
# plot validation accuracy
colors = [results[x][1] for x in results] # default size of markers is 20
plt.subplot(2, 1, 2)

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

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

```

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

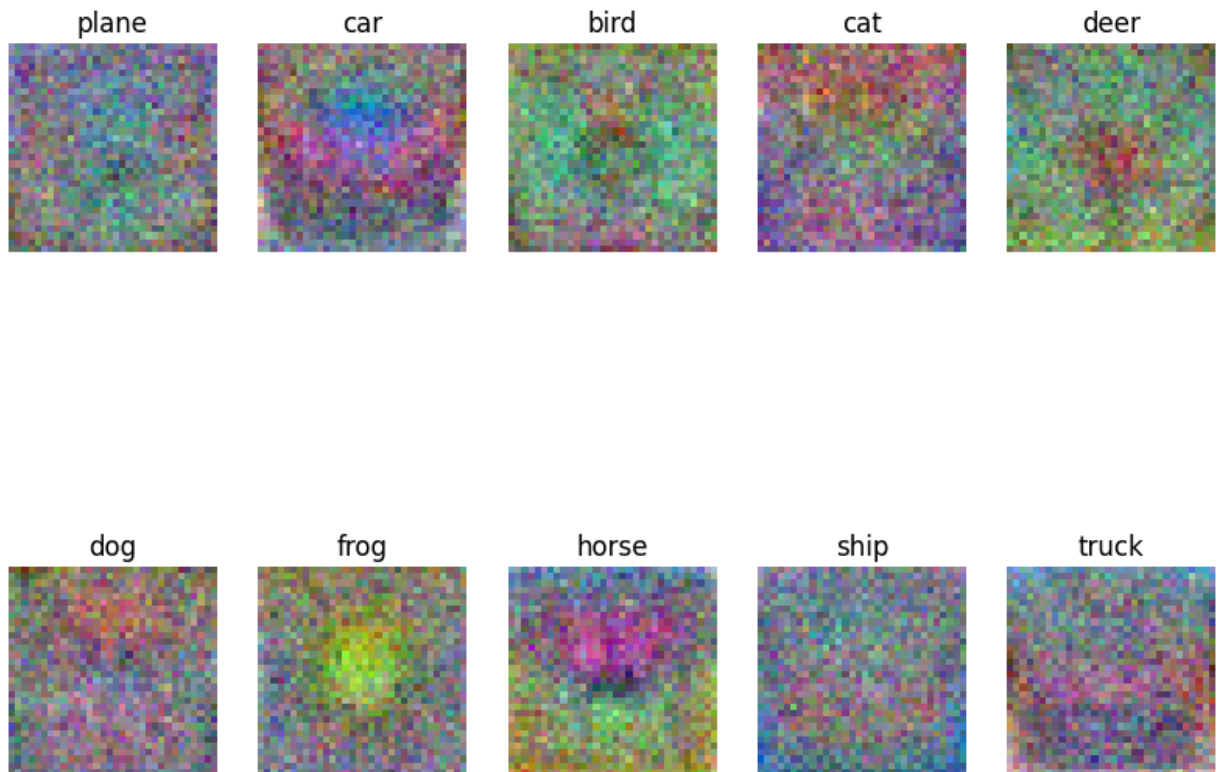


```
In [ ]: # Evaluate the best svm on test set
y_test_pred = best_svm.predict(X_test)
test_accuracy = np.mean(y_test == y_test_pred)
print('linear SVM on raw pixels final test set accuracy: %f' % test_accuracy)
```

linear SVM on raw pixels final test set accuracy: 0.379000

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



## Inline question 2:

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

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