Chapter 10 - Deep Learning

September 14, 2023

```
[97]: !pip install ISLP
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Requirement already satisfied: ISLP in
/Users/barnana/anaconda3/lib/python3.10/site-packages (0.3.16)
Requirement already satisfied: pandas>=0.0 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from ISLP) (1.5.3)
Requirement already satisfied: numpy>=0.0 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from ISLP) (1.25.1)
Requirement already satisfied: pygam>=0.0 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from ISLP) (0.9.0)
Requirement already satisfied: scipy>=0.9 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from ISLP) (1.11.1)
Requirement already satisfied: jupyter>=0.0 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from ISLP) (1.0.0)
Requirement already satisfied: statsmodels>=0.13 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from ISLP) (0.13.5)
Requirement already satisfied: lifelines>=0.0 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from ISLP) (0.27.7)
Requirement already satisfied: scikit-learn>=1.2 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from ISLP) (1.3.0)
Requirement already satisfied: joblib>=0.0 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from ISLP) (1.1.1)
Requirement already satisfied: matplotlib>=3.3.3 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from ISLP) (3.7.0)
Requirement already satisfied: lxml>=0.0 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from ISLP) (4.9.1)
Requirement already satisfied: ipykernel in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from jupyter>=0.0->ISLP)
(6.19.2)
Requirement already satisfied: nbconvert in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from jupyter>=0.0->ISLP)
(6.5.4)
Requirement already satisfied: qtconsole in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from jupyter>=0.0->ISLP)
(5.4.0)
Requirement already satisfied: jupyter-console in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from jupyter>=0.0->ISLP)
(6.6.3)

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Requirement already satisfied: ipywidgets in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from jupyter>=0.0->ISLP)
(8.0.7)
Requirement already satisfied: notebook in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from jupyter>=0.0->ISLP)
(6.5.2)
Requirement already satisfied: autograd>=1.5 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
lifelines>=0.0->ISLP) (1.6.2)
Requirement already satisfied: formulaic>=0.2.2 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
lifelines>=0.0->ISLP) (0.6.4)
Requirement already satisfied: autograd-gamma>=0.3 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
lifelines>=0.0->ISLP) (0.5.0)
Requirement already satisfied: python-dateutil>=2.7 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
matplotlib>=3.3.3->ISLP) (2.8.2)
Requirement already satisfied: cycler>=0.10 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
matplotlib>=3.3.3->ISLP) (0.11.0)
Requirement already satisfied: pillow>=6.2.0 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
matplotlib>=3.3.3->ISLP) (9.4.0)
Requirement already satisfied: packaging>=20.0 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
matplotlib>=3.3.3->ISLP) (22.0)
Requirement already satisfied: contourpy>=1.0.1 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
matplotlib>=3.3.3->ISLP) (1.0.5)
Requirement already satisfied: kiwisolver>=1.0.1 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
matplotlib>=3.3.3->ISLP) (1.4.4)
Requirement already satisfied: pyparsing>=2.3.1 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
matplotlib>=3.3.3->ISLP) (3.0.9)
Requirement already satisfied: fonttools>=4.22.0 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
matplotlib>=3.3.3->ISLP) (4.25.0)
Requirement already satisfied: pytz>=2020.1 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from pandas>=0.0->ISLP)
(2022.7)
Requirement already satisfied: progressbar2<5.0.0,>=4.2.0 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from pygam>=0.0->ISLP)
(4.2.0)
Requirement already satisfied: threadpoolctl>=2.0.0 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from scikit-
learn>=1.2->ISLP) (3.2.0)
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Requirement already satisfied: patsy>=0.5.2 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
statsmodels>=0.13->ISLP) (0.5.3)
Requirement already satisfied: future>=0.15.2 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
autograd>=1.5->lifelines>=0.0->ISLP) (0.18.3)
Requirement already satisfied: wrapt>=1.0 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
formulaic>=0.2.2->lifelines>=0.0->ISLP) (1.14.1)
Requirement already satisfied: typing-extensions>=4.2.0 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
formulaic>=0.2.2->lifelines>=0.0->ISLP) (4.4.0)
Requirement already satisfied: astor>=0.8 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
formulaic>=0.2.2->lifelines>=0.0->ISLP) (0.8.1)
Requirement already satisfied: interface-meta>=1.2.0 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
formulaic>=0.2.2->lifelines>=0.0->ISLP) (1.3.0)
Requirement already satisfied: six in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
patsy>=0.5.2->statsmodels>=0.13->ISLP) (1.16.0)
Requirement already satisfied: python-utils>=3.0.0 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
progressbar2<5.0.0,>=4.2.0->pygam>=0.0->ISLP) (3.7.0)
Requirement already satisfied: comm>=0.1.1 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
ipykernel->jupyter>=0.0->ISLP) (0.1.2)
Requirement already satisfied: ipython>=7.23.1 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
ipykernel->jupyter>=0.0->ISLP) (8.10.0)
Requirement already satisfied: pyzmq>=17 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
ipykernel->jupyter>=0.0->ISLP) (23.2.0)
Requirement already satisfied: psutil in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
ipykernel->jupyter>=0.0->ISLP) (5.9.0)
Requirement already satisfied: traitlets>=5.4.0 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
ipykernel->jupyter>=0.0->ISLP) (5.7.1)
Requirement already satisfied: tornado>=6.1 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
ipykernel->jupyter>=0.0->ISLP) (6.1)
Requirement already satisfied: matplotlib-inline>=0.1 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
ipykernel->jupyter>=0.0->ISLP) (0.1.6)
Requirement already satisfied: nest-asyncio in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
ipykernel->jupyter>=0.0->ISLP) (1.5.6)
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Requirement already satisfied: jupyter-client>=6.1.12 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
ipykernel->jupyter>=0.0->ISLP) (7.3.4)
Requirement already satisfied: debugpy>=1.0 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
ipykernel->jupyter>=0.0->ISLP) (1.5.1)
Requirement already satisfied: appnope in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
ipykernel->jupyter>=0.0->ISLP) (0.1.2)
Requirement already satisfied: widgetsnbextension~=4.0.7 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
ipywidgets->jupyter>=0.0->ISLP) (4.0.8)
Requirement already satisfied: jupyterlab-widgets~=3.0.7 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
ipywidgets->jupyter>=0.0->ISLP) (3.0.8)
Requirement already satisfied: prompt-toolkit>=3.0.30 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from jupyter-
console->jupyter>=0.0->ISLP) (3.0.36)
Requirement already satisfied: jupyter-core!=5.0.*,>=4.12 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from jupyter-
console->jupyter>=0.0->ISLP) (5.2.0)
Requirement already satisfied: pygments in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from jupyter-
console->jupyter>=0.0->ISLP) (2.11.2)
Requirement already satisfied: pandocfilters>=1.4.1 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
nbconvert->jupyter>=0.0->ISLP) (1.5.0)
Requirement already satisfied: tinycss2 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
nbconvert->jupyter>=0.0->ISLP) (1.2.1)
Requirement already satisfied: entrypoints>=0.2.2 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
nbconvert->jupyter>=0.0->ISLP) (0.4)
Requirement already satisfied: MarkupSafe>=2.0 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
nbconvert->jupyter>=0.0->ISLP) (2.1.1)
Requirement already satisfied: nbformat>=5.1 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
nbconvert->jupyter>=0.0->ISLP) (5.7.0)
Requirement already satisfied: bleach in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
nbconvert->jupyter>=0.0->ISLP) (4.1.0)
Requirement already satisfied: jinja2>=3.0 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
nbconvert->jupyter>=0.0->ISLP) (3.1.2)
Requirement already satisfied: beautifulsoup4 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
nbconvert->jupyter>=0.0->ISLP) (4.11.1)
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Requirement already satisfied: mistune<2,>=0.8.1 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
nbconvert->jupyter>=0.0->ISLP) (0.8.4)
Requirement already satisfied: nbclient>=0.5.0 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
nbconvert->jupyter>=0.0->ISLP) (0.5.13)
Requirement already satisfied: jupyterlab-pygments in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
nbconvert->jupyter>=0.0->ISLP) (0.1.2)
Requirement already satisfied: defusedxml in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
nbconvert->jupyter>=0.0->ISLP) (0.7.1)
Requirement already satisfied: ipython-genutils in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
notebook->jupyter>=0.0->ISLP) (0.2.0)
Requirement already satisfied: prometheus-client in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
notebook->jupyter>=0.0->ISLP) (0.14.1)
Requirement already satisfied: Send2Trash>=1.8.0 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
notebook->jupyter>=0.0->ISLP) (1.8.0)
Requirement already satisfied: terminado>=0.8.3 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
notebook->jupyter>=0.0->ISLP) (0.17.1)
Requirement already satisfied: argon2-cffi in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
notebook->jupyter>=0.0->ISLP) (21.3.0)
Requirement already satisfied: nbclassic>=0.4.7 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
notebook->jupyter>=0.0->ISLP) (0.5.2)
Requirement already satisfied: qtpy>=2.0.1 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
qtconsole->jupyter>=0.0->ISLP) (2.2.0)
Requirement already satisfied: decorator in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
ipython>=7.23.1->ipykernel->jupyter>=0.0->ISLP) (5.1.1)
Requirement already satisfied: jedi>=0.16 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
ipython>=7.23.1->ipykernel->jupyter>=0.0->ISLP) (0.18.1)
Requirement already satisfied: stack-data in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
ipython>=7.23.1->ipykernel->jupyter>=0.0->ISLP) (0.2.0)
Requirement already satisfied: pexpect>4.3 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
ipython>=7.23.1->ipykernel->jupyter>=0.0->ISLP) (4.8.0)
Requirement already satisfied: pickleshare in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
ipython>=7.23.1->ipykernel->jupyter>=0.0->ISLP) (0.7.5)
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Requirement already satisfied: backcall in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
ipython>=7.23.1->ipykernel->jupyter>=0.0->ISLP) (0.2.0)
Requirement already satisfied: platformdirs>=2.5 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from jupyter-
core!=5.0.*,>=4.12->jupyter-console->jupyter>=0.0->ISLP) (2.5.2)
Requirement already satisfied: notebook-shim>=0.1.0 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
nbclassic>=0.4.7->notebook->jupyter>=0.0->ISLP) (0.2.2)
Requirement already satisfied: jupyter-server>=1.8 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
nbclassic>=0.4.7->notebook->jupyter>=0.0->ISLP) (1.23.4)
Requirement already satisfied: fastjsonschema in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
nbformat>=5.1->nbconvert->jupyter>=0.0->ISLP) (2.16.2)
Requirement already satisfied: jsonschema>=2.6 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
nbformat>=5.1->nbconvert->jupyter>=0.0->ISLP) (4.17.3)
Requirement already satisfied: wcwidth in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from prompt-
toolkit>=3.0.30->jupyter-console->jupyter>=0.0->ISLP) (0.2.5)
Requirement already satisfied: ptyprocess in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
terminado>=0.8.3->notebook->jupyter>=0.0->ISLP) (0.7.0)
Requirement already satisfied: argon2-cffi-bindings in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
argon2-cffi->notebook->jupyter>=0.0->ISLP) (21.2.0)
Requirement already satisfied: soupsieve>1.2 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
beautifulsoup4->nbconvert->jupyter>=0.0->ISLP) (2.3.2.post1)
Requirement already satisfied: webencodings in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
bleach->nbconvert->jupyter>=0.0->ISLP) (0.5.1)
Requirement already satisfied: parso<0.9.0,>=0.8.0 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
jedi>=0.16->ipython>=7.23.1->ipykernel->jupyter>=0.0->ISLP) (0.8.3)
Requirement already satisfied: pyrsistent!=0.17.0,!=0.17.1,!=0.17.2,>=0.14.0 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
jsonschema>=2.6->nbformat>=5.1->nbconvert->jupyter>=0.0->ISLP) (0.18.0)
Requirement already satisfied: attrs>=17.4.0 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
jsonschema>=2.6->nbformat>=5.1->nbconvert->jupyter>=0.0->ISLP) (22.1.0)
Requirement already satisfied: websocket-client in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from jupyter-
server>=1.8->nbclassic>=0.4.7->notebook->jupyter>=0.0->ISLP) (0.58.0)
Requirement already satisfied: anyio<4,>=3.1.0 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from jupyter-
server>=1.8->nbclassic>=0.4.7->notebook->jupyter>=0.0->ISLP) (3.5.0)
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Requirement already satisfied: cffi>=1.0.1 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from argon2-cffi-
bindings->argon2-cffi->notebook->jupyter>=0.0->ISLP) (1.15.1)
Requirement already satisfied: executing in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from stack-
data->ipython>=7.23.1->ipykernel->jupyter>=0.0->ISLP) (0.8.3)
Requirement already satisfied: pure-eval in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from stack-
data->ipython>=7.23.1->ipykernel->jupyter>=0.0->ISLP) (0.2.2)
Requirement already satisfied: asttokens in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from stack-
data->ipython>=7.23.1->ipykernel->jupyter>=0.0->ISLP) (2.0.5)
Requirement already satisfied: sniffio>=1.1 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
anyio<4,>=3.1.0->jupyter-
server>=1.8->nbclassic>=0.4.7->notebook->jupyter>=0.0->ISLP) (1.2.0)
Requirement already satisfied: idna>=2.8 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
anyio<4,>=3.1.0->jupyter-
server>=1.8->nbclassic>=0.4.7->notebook->jupyter>=0.0->ISLP) (3.4)
Requirement already satisfied: pycparser in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
cffi>=1.0.1->argon2-cffi-bindings->argon2-cffi->notebook->jupyter>=0.0->ISLP)
(2.21)

```
[98]: !pip install pytorch-lightning
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Requirement already satisfied: pytorch-lightning in
/Users/barnana/anaconda3/lib/python3.10/site-packages (2.0.6)
Requirement already satisfied: typing-extensions>=4.0.0 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from pytorch-lightning)
(4.4.0)
Requirement already satisfied: fsspec[http]>2021.06.0 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from pytorch-lightning)
(2022.11.0)
Requirement already satisfied: tqdm>=4.57.0 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from pytorch-lightning)
(4.64.1)
Requirement already satisfied: lightning-utilities>=0.7.0 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from pytorch-lightning)
(0.9.0)
Requirement already satisfied: PyYAML>=5.4 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from pytorch-lightning)
(6.0)
Requirement already satisfied: torch>=1.11.0 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from pytorch-lightning)
(1.12.1)
Requirement already satisfied: torchmetrics>=0.7.0 in

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/Users/barnana/anaconda3/lib/python3.10/site-packages (from pytorch-lightning)
(1.0.1)
Requirement already satisfied: numpy>=1.17.2 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from pytorch-lightning)
(1.25.1)
Requirement already satisfied: packaging>=17.1 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from pytorch-lightning)
(22.0)
Requirement already satisfied: aiohttp!=4.0.0a0,!=4.0.0a1 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
fsspec[http]>2021.06.0->pytorch-lightning) (3.8.5)
Requirement already satisfied: requests in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
fsspec[http]>2021.06.0->pytorch-lightning) (2.28.1)
Requirement already satisfied: async-timeout<5.0,>=4.0.0a3 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
aiohttp!=4.0.0a0,!=4.0.0a1->fsspec[http]>2021.06.0->pytorch-lightning) (4.0.2)
Requirement already satisfied: multidict<7.0,>=4.5 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
aiohttp!=4.0.0a0,!=4.0.0a1->fsspec[http]>2021.06.0->pytorch-lightning) (6.0.4)
Requirement already satisfied: aiosignal>=1.1.2 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
aiohttp!=4.0.0a0,!=4.0.0a1->fsspec[http]>2021.06.0->pytorch-lightning) (1.3.1)
Requirement already satisfied: charset-normalizer<4.0,>=2.0 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
aiohttp!=4.0.0a0,!=4.0.0a1->fsspec[http]>2021.06.0->pytorch-lightning) (2.0.4)
Requirement already satisfied: attrs>=17.3.0 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
aiohttp!=4.0.0a0,!=4.0.0a1->fsspec[http]>2021.06.0->pytorch-lightning) (22.1.0)
Requirement already satisfied: frozenlist>=1.1.1 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
aiohttp!=4.0.0a0,!=4.0.0a1->fsspec[http]>2021.06.0->pytorch-lightning) (1.4.0)
Requirement already satisfied: yarl<2.0,>=1.0 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
aiohttp!=4.0.0a0,!=4.0.0a1->fsspec[http]>2021.06.0->pytorch-lightning) (1.9.2)
Requirement already satisfied: certifi>=2017.4.17 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
requests->fsspec[http]>2021.06.0->pytorch-lightning) (2023.5.7)
Requirement already satisfied: idna<4,>=2.5 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
requests->fsspec[http]>2021.06.0->pytorch-lightning) (3.4)
Requirement already satisfied: urllib3<1.27,>=1.21.1 in
/Users/barnana/anaconda3/lib/python3.10/site-packages (from
requests->fsspec[http]>2021.06.0->pytorch-lightning) (1.26.14)
```

```python
[99]: from ISLP import load_data
      import pandas as pd
```

```python
import numpy as np
import seaborn as sns
import math
import matplotlib.pyplot as plt
import statsmodels.api as sm
from sklearn.preprocessing import StandardScaler, OneHotEncoder
from sklearn.model_selection import train_test_split, GridSearchCV, KFold,
 ↪cross_val_score
from sklearn.linear_model import LinearRegression
from sklearn.metrics import mean_squared_error
from sklearn.linear_model import RidgeCV
from sklearn.linear_model import LassoCV
from sklearn.decomposition import PCA
from sklearn.pipeline import Pipeline
from sklearn.cross_decomposition import PLSRegression
import itertools
from sklearn.tree import plot_tree
from sklearn.tree import DecisionTreeRegressor
from sklearn.ensemble import BaggingRegressor
from sklearn.ensemble import RandomForestRegressor
from sklearn.ensemble import GradientBoostingClassifier
from sklearn.metrics import accuracy_score, confusion_matrix
from sklearn.neighbors import KNeighborsClassifier
from sklearn.linear_model import LogisticRegression
import warnings
warnings.filterwarnings("ignore", category=FutureWarning)
warnings.filterwarnings("ignore", category=DeprecationWarning)
import torch
import torch.nn as nn
import torch.nn.functional as F
from sklearn.metrics import classification_report
```

```python
[100]: # Creating a function to print output in green and bold
       # ANSI escape code for green color and bold font
       GREEN_BOLD = '\033[1;32m'

       # ANSI escape code to reset colors and font style
       RESET = '\033[0m'

       def print_green_bold(*args):
           text = ' '.join(str(arg) for arg in args)
           print(GREEN_BOLD + text + RESET)
```

1 Chapter 10

1.1 Question 7

Fit a neural network to the Default data. Use a single hidden layer with 10 units, and dropout regularization. Have a look at Labs 10.9.1– 10.9.2 for guidance. Compare the classification performance of your model with that of linear logistic regression.

```
[160]: default_c10q7=load_data('Default')
       default_c10q7.head(50)
```

```
[160]:    default student      balance        income
       0       No      No   729.526495  44361.625074
       1       No     Yes   817.180407  12106.134700
       2       No      No  1073.549164  31767.138947
       3       No      No   529.250605  35704.493935
       4       No      No   785.655883  38463.495879
       5       No     Yes   919.588530   7491.558572
       6       No      No   825.513331  24905.226578
       7       No     Yes   808.667504  17600.451344
       8       No      No  1161.057854  37468.529288
       9       No      No     0.000000  29275.268293
       10      No     Yes     0.000000  21871.073089
       11      No     Yes  1220.583753  13268.562221
       12      No      No   237.045114  28251.695345
       13      No      No   606.742343  44994.555849
       14      No      No  1112.968401  23810.174050
       15      No      No   286.232560  45042.413036
       16      No      No     0.000000  50265.312354
       17      No     Yes   527.540184  17636.539617
       18      No      No   485.936864  61566.106118
       19      No      No  1095.072735  26464.631389
       20      No      No   228.952550  50500.182198
       21      No      No   954.261793  32457.509075
       22      No      No  1055.956605  51317.883082
       23      No      No   641.984389  30466.103257
       24      No      No   773.211725  34353.314305
       25      No      No   855.008523  25211.332161
       26      No      No   642.999739  41473.511801
       27      No      No  1454.863272  32189.094952
       28      No      No   615.704277  39376.394619
       29      No     Yes  1119.569353  16556.070205
       30      No      No   494.816229  54384.782836
       31      No     Yes   448.880656  15799.470410
       32      No     Yes   584.904895  22429.935046
       33      No      No   913.587173  46907.225403
       34      No     Yes  1423.938917  22634.488088
       35      No     Yes  1499.724657  13190.652716
```

```
36     No      No    692.034167   47806.611773
37     No      No    351.453472   35087.488648
38     No      No    742.627621   37864.823939
39     No      No    653.118400   39489.594703
40     No      No    872.138680   41787.567269
41     No      No    837.262623   51471.772095
42     No      No   1151.630566   42917.469564
43     No     Yes    220.555608   16872.947556
44     No     Yes   1690.234410   19052.572225
45     No      No    408.772914   54206.939212
46     No      No   1238.610321   50066.680534
47     No      No   1228.308350   37408.503869
48     No      No    820.919204   47746.542073
49     No      No    857.485118   31688.345974
```

[161]:
```python
# Encode categorical variables
df_c10q7=default_c10q7.copy()
df_c10q7 = pd.get_dummies(df_c10q7, columns=['default', 'student'],
 ↪drop_first=True)

# Scale continuous variables
scaler = StandardScaler()
df_c10q7[['balance', 'income']] = scaler.fit_transform(df_c10q7[['balance',
 ↪'income']])

# Split the dataset into train and test
train_df_c10q7, test_df_c10q7 = train_test_split(df_c10q7, test_size=0.2,
 ↪random_state=42)
```

[162]:
```python
# Convert DataFrames to Tensors
train_features_c10q7 = torch.tensor(train_df_c10q7.drop('default_Yes', axis=1).
 ↪values, dtype=torch.float)
train_targets_c10q7 = torch.tensor(train_df_c10q7['default_Yes'].values,
 ↪dtype=torch.float)
test_features_c10q7 = torch.tensor(test_df_c10q7.drop('default_Yes', axis=1).
 ↪values, dtype=torch.float)
test_targets_c10q7 = torch.tensor(test_df_c10q7['default_Yes'].values,
 ↪dtype=torch.float)
```

[163]:
```python
class DefaultModel(nn.Module):
    def __init__(self, input_size):
        super(DefaultModel, self).__init__()
        self.layer1 = nn.Linear(input_size, 10)
        self.layer2 = nn.Dropout(0.5)
        self.layer3 = nn.Linear(10, 1)

    def forward(self, x):
```

```
        x = F.relu(self.layer1(x))
        x = self.layer2(x)
        x = torch.sigmoid(self.layer3(x))
        return x
```

[164]:
```python
# Initialize the model, loss, and optimizer
model_c10q7 = DefaultModel(input_size=train_features_c10q7.shape[1])
criterion_c10q7 = nn.BCELoss()
optimizer_c10q7 = torch.optim.Adam(model_c10q7.parameters(), lr=0.01)

# Training loop
print_green_bold('Starting training. The Training Loss is the error rate on the␣
 ↪training set, which we aim to minimize during training.')
for epoch in range(100):   # 100 epochs
    outputs_c10q7 = model_c10q7(train_features_c10q7).squeeze()
    loss_c10q7 = criterion_c10q7(outputs_c10q7, train_targets_c10q7)

    optimizer_c10q7.zero_grad()
    loss_c10q7.backward()
    optimizer_c10q7.step()

    if (epoch+1) % 10 == 0:  # print loss every 10 epochs
        print_green_bold(f'Epoch {epoch+1}/{100}, Training Loss: {loss_c10q7.
 ↪item()}')
```

Starting training. The Training Loss is the error rate on the training

set, which we aim to minimize during training.
Epoch 10/100, Training Loss: 0.4406525790691376
Epoch 20/100, Training Loss: 0.3220202922821045
Epoch 30/100, Training Loss: 0.23933091759681702
Epoch 40/100, Training Loss: 0.1913415938615799
Epoch 50/100, Training Loss: 0.1648746132850647
Epoch 60/100, Training Loss: 0.1435428112745285
Epoch 70/100, Training Loss: 0.13353966176509857
Epoch 80/100, Training Loss: 0.12388017028570175
Epoch 90/100, Training Loss: 0.11699888855218887
Epoch 100/100, Training Loss: 0.1101469025015831

[165]:
```python
# Set the model to evaluation mode
model_c10q7.eval()

# Do not compute gradients for this step
with torch.no_grad():
    test_outputs_c10q7 = model_c10q7(test_features_c10q7).squeeze() # Forward␣
 ↪pass
```

```
        test_loss_c10q7 = criterion_c10q7(test_outputs_c10q7, test_targets_c10q7) #␣
    ↪Compute loss

        # Convert outputs to probability values (0 to 1) and then to class labels
        test_preds_c10q7 = torch.where(test_outputs_c10q7 > 0.5, torch.
    ↪ones_like(test_outputs_c10q7), torch.zeros_like(test_outputs_c10q7))

        # Calculate accuracy
        accuracy_c10q7 = (test_preds_c10q7 == test_targets_c10q7).type(torch.
    ↪float32).mean().item()

print_green_bold(f'Test Loss: {test_loss_c10q7.item()}')
print_green_bold(f'Test Accuracy: {accuracy_c10q7}')
```

Test Loss: 0.09956272691488266
Test Accuracy: 0.965499997138977

Now we train a logistic regression model and compare.

```
[166]: # Separate features (X) and target (y)
       X_c10q7 = train_df_c10q7.drop(columns=['default_Yes'])
       y_c10q7 = train_df_c10q7['default_Yes']

       # Split the data into training and testing sets
       X_train_c10q7, X_test_c10q7, y_train_c10q7, y_test_c10q7 =␣
        ↪train_test_split(X_c10q7, y_c10q7, test_size=0.3, random_state=42)

       # Initialize and train a logistic regression model
       log_reg_c10q7 = LogisticRegression()
       log_reg_c10q7.fit(X_train_c10q7, y_train_c10q7)

       # Make predictions
       log_reg_preds_c10q7 = log_reg_c10q7.predict(X_test_c10q7)

       # Compare metrics
       print_green_bold("Logistic Regression Performance:")
       print_green_bold(classification_report(y_test_c10q7, log_reg_preds_c10q7,␣
        ↪zero_division=1))

       # You already have your PyTorch model predictions. Let's assume they're stored␣
        ↪in `test_preds`
       print_green_bold("Neural Network Performance:")
       print_green_bold(classification_report(test_targets_c10q7.numpy(),␣
        ↪test_preds_c10q7.numpy(), zero_division=1))
```

Logistic Regression Performance:

	precision	recall	f1-score	support
0	0.98	1.00	0.99	2317
1	0.90	0.33	0.48	83
accuracy			0.98	2400
macro avg	0.94	0.66	0.73	2400
weighted avg	0.97	0.98	0.97	2400

Neural Network Performance:

	precision	recall	f1-score	support
0.0	0.97	1.00	0.98	1931
1.0	1.00	0.00	0.00	69
accuracy			0.97	2000
macro avg	0.98	0.50	0.49	2000
weighted avg	0.97	0.97	0.95	2000

Precision: The Logistic Regression model has a precision of 0.90, meaning that when it predicts a default (class 1), it is correct 90% of the time. On the other hand, the Neural Network has a precision of 1.00, indicating that it always predicts class 1 correctly, but this is misleading given the recall value.

Recall: The Logistic Regression model has a recall of 0.33, suggesting that it can correctly identify 33% of the actual defaults in the dataset. The Neural Network, surprisingly, has a recall of 0.00, meaning it fails to detect any defaults at all.

Accuracy: Both models have relatively high accuracy, with the Logistic Regression at 0.98 and the Neural Network at 0.97. However, accuracy alone can be misleading, especially when dealing with imbalanced datasets.

Overall, the Logistic Regression model outperforms the Neural Network in predicting defaults. While the Neural Network has perfect precision for defaults, its recall is extremely low, meaning it is failing to capture any true defaults. The Logistic Regression, despite having a lower precision, has a better balance of precision and recall, resulting in a higher F1-score and overall better performance in this specific context.

[ ]: