

```
In [15]: import sys
print("Using Python from:", sys.executable)
```

```
!{sys.executable} -m pip install --upgrade --force-reinstall numpy
```

Using Python from: /opt/anaconda3/envs/ImageProcessingProject/bin/python

Collecting numpy

Using cached numpy-2.3.4-cp312-cp312-macosx_14_0_x86_64.whl.metadata (62 kB)

Using cached numpy-2.3.4-cp312-cp312-macosx_14_0_x86_64.whl (6.6 MB)

Installing collected packages: numpy

Attempting uninstall: numpy

Found existing installation: numpy 1.26.4

Uninstalling numpy-1.26.4:

Successfully uninstalled numpy-1.26.4

ERROR: pip's dependency resolver does not currently take into account all the packages that are installed. This behaviour is the source of the following dependency conflict s.

tensorflow 2.16.2 requires numpy<2.0.0,>=1.26.0; python_version >= "3.12", but you have numpy 2.3.4 which is incompatible.

Successfully installed numpy-2.3.4

```
In [16]: import sys
print("Using Python from:", sys.executable)
```

```
!{sys.executable} -m pip install --upgrade --force-reinstall numpy matplotlib scikit-
```

```
Using Python from: /opt/anaconda3/envs/ImageProcessingProject/bin/python
Collecting numpy
  Using cached numpy-2.3.4-cp312-cp312-macosx_14_0_x86_64.whl.metadata (62 kB)
Collecting matplotlib
  Using cached matplotlib-3.10.7-cp312-cp312-macosx_10_13_x86_64.whl.metadata (11 kB)
Collecting scikit-learn
  Using cached scikit_learn-1.7.2-cp312-cp312-macosx_10_13_x86_64.whl.metadata (11 kB)
Collecting tensorflow
  Using cached tensorflow-2.16.2-cp312-cp312-macosx_10_15_x86_64.whl.metadata (4.1 kB)
Collecting contourpy>=1.0.1 (from matplotlib)
  Using cached contourpy-1.3.3-cp312-cp312-macosx_10_13_x86_64.whl.metadata (5.5 kB)
Collecting cycler>=0.10 (from matplotlib)
  Using cached cycler-0.12.1-py3-none-any.whl.metadata (3.8 kB)
Collecting fonttools>=4.22.0 (from matplotlib)
  Using cached fonttools-4.60.1-cp312-cp312-macosx_10_13_x86_64.whl.metadata (112 kB)
Collecting kiwisolver>=1.3.1 (from matplotlib)
  Using cached kiwisolver-1.4.9-cp312-cp312-macosx_10_13_x86_64.whl.metadata (6.3 kB)
Collecting packaging>=20.0 (from matplotlib)
  Using cached packaging-25.0-py3-none-any.whl.metadata (3.3 kB)
Collecting pillow>=8 (from matplotlib)
  Using cached pillow-12.0.0-cp312-cp312-macosx_10_13_x86_64.whl.metadata (8.8 kB)
Collecting pyparsing>=3 (from matplotlib)
  Using cached pyparsing-3.2.5-py3-none-any.whl.metadata (5.0 kB)
Collecting python-dateutil>=2.7 (from matplotlib)
  Using cached python_dateutil-2.9.0.post0-py2.py3-none-any.whl.metadata (8.4 kB)
Collecting scipy>=1.8.0 (from scikit-learn)
  Using cached scipy-1.16.3-cp312-cp312-macosx_14_0_x86_64.whl.metadata (62 kB)
Collecting joblib>=1.2.0 (from scikit-learn)
  Using cached joblib-1.5.2-py3-none-any.whl.metadata (5.6 kB)
Collecting threadpoolctl>=3.1.0 (from scikit-learn)
  Using cached threadpoolctl-3.6.0-py3-none-any.whl.metadata (13 kB)
Collecting absl-py>=1.0.0 (from tensorflow)
  Using cached absl_py-2.3.1-py3-none-any.whl.metadata (3.3 kB)
Collecting astunparse>=1.6.0 (from tensorflow)
  Using cached astunparse-1.6.3-py2.py3-none-any.whl.metadata (4.4 kB)
Collecting flatbuffers>=23.5.26 (from tensorflow)
  Using cached flatbuffers-25.9.23-py2.py3-none-any.whl.metadata (875 bytes)
Collecting gast!=0.5.0,!=0.5.1,!=0.5.2,>=0.2.1 (from tensorflow)
  Using cached gast-0.6.0-py3-none-any.whl.metadata (1.3 kB)
Collecting google-pasta>=0.1.1 (from tensorflow)
  Using cached google_pasta-0.2.0-py3-none-any.whl.metadata (814 bytes)
Collecting h5py>=3.10.0 (from tensorflow)
  Using cached h5py-3.15.1-cp312-cp312-macosx_10_13_x86_64.whl.metadata (3.0 kB)
Collecting libclang>=13.0.0 (from tensorflow)
  Using cached libclang-18.1.1-py2.py3-none-macosx_10_9_x86_64.whl.metadata (5.2 kB)
Collecting ml-dtypes~=0.3.1 (from tensorflow)
  Using cached ml_dtypes-0.3.2-cp312-cp312-macosx_10_9_universal2.whl.metadata (20 kB)
Collecting opt-einsum>=2.3.2 (from tensorflow)
  Using cached opt_einsum-3.4.0-py3-none-any.whl.metadata (6.3 kB)
Collecting protobuf!=4.21.0,!=4.21.1,!=4.21.2,!=4.21.3,!=4.21.4,!=4.21.5,<5.0.0dev,>=3.20.3 (from tensorflow)
  Using cached protobuf-4.25.8-cp37-abi3-macosx_10_9_universal2.whl.metadata (541 byte
s)
Collecting requests<3,>=2.21.0 (from tensorflow)
  Using cached requests-2.32.5-py3-none-any.whl.metadata (4.9 kB)
Collecting setuptools (from tensorflow)
  Using cached setuptools-80.9.0-py3-none-any.whl.metadata (6.6 kB)
Collecting six>=1.12.0 (from tensorflow)
  Using cached six-1.17.0-py2.py3-none-any.whl.metadata (1.7 kB)
Collecting termcolor>=1.1.0 (from tensorflow)
  Using cached termcolor-3.2.0-py3-none-any.whl.metadata (6.4 kB)
Collecting typing-extensions>=3.6.6 (from tensorflow)
  Using cached typing_extensions-4.15.0-py3-none-any.whl.metadata (3.3 kB)
Collecting wrapt>=1.11.0 (from tensorflow)
  Using cached wrapt-2.0.1-cp312-cp312-macosx_10_13_x86_64.whl.metadata (9.0 kB)
Collecting grpcio<2.0,>=1.24.3 (from tensorflow)
```

Using cached grpcio-1.76.0-cp312-cp312-macosx_11_0_universal2.whl.metadata (3.7 kB)
Collecting tensorboard<2.17,>=2.16 (from tensorflow)
Using cached tensorboard-2.16.2-py3-none-any.whl.metadata (1.6 kB)
Collecting keras>=3.0.0 (from tensorflow)
Using cached keras-3.12.0-py3-none-any.whl.metadata (5.9 kB)
Collecting numpy
Using cached numpy-1.26.4-cp312-cp312-macosx_10_9_x86_64.whl.metadata (61 kB)
Collecting charset_normalizer<4,>=2 (from requests<3,>=2.21.0->tensorflow)
Using cached charset_normalizer-3.4.4-cp312-cp312-macosx_10_13_universal2.whl.metada
ta (37 kB)
Collecting idna<4,>=2.5 (from requests<3,>=2.21.0->tensorflow)
Using cached idna-3.11-py3-none-any.whl.metadata (8.4 kB)
Collecting urllib3<3,>=1.21.1 (from requests<3,>=2.21.0->tensorflow)
Using cached urllib3-2.5.0-py3-none-any.whl.metadata (6.5 kB)
Collecting certifi>=2017.4.17 (from requests<3,>=2.21.0->tensorflow)
Using cached certifi-2025.11.12-py3-none-any.whl.metadata (2.5 kB)
Collecting markdown>=2.6.8 (from tensorboard<2.17,>=2.16->tensorflow)
Using cached markdown-3.10-py3-none-any.whl.metadata (5.1 kB)
Collecting tensorboard-data-server<0.8.0,>=0.7.0 (from tensorboard<2.17,>=2.16->tensor
flow)
Using cached tensorboard_data_server-0.7.2-py3-none-macosx_10_9_x86_64.whl.metadata
(1.1 kB)
Collecting werkzeug>=1.0.1 (from tensorboard<2.17,>=2.16->tensorflow)
Using cached werkzeug-3.1.3-py3-none-any.whl.metadata (3.7 kB)
Collecting wheel<1.0,>=0.23.0 (from astunparse>=1.6.0->tensorflow)
Using cached wheel-0.45.1-py3-none-any.whl.metadata (2.3 kB)
Collecting rich (from keras>=3.0.0->tensorflow)
Using cached rich-14.2.0-py3-none-any.whl.metadata (18 kB)
Collecting namex (from keras>=3.0.0->tensorflow)
Using cached namex-0.1.0-py3-none-any.whl.metadata (322 bytes)
Collecting optree (from keras>=3.0.0->tensorflow)
Using cached optree-0.18.0-cp312-cp312-macosx_10_13_x86_64.whl.metadata (34 kB)
Collecting MarkupSafe>=2.1.1 (from werkzeug>=1.0.1->tensorboard<2.17,>=2.16->tensorflo
w)
Using cached markupsafe-3.0.3-cp312-cp312-macosx_10_13_x86_64.whl.metadata (2.7 kB)
Collecting markdown-it-py>=2.2.0 (from rich->keras>=3.0.0->tensorflow)
Using cached markdown_it_py-4.0.0-py3-none-any.whl.metadata (7.3 kB)
Collecting pygments<3.0.0,>=2.13.0 (from rich->keras>=3.0.0->tensorflow)
Using cached pygments-2.19.2-py3-none-any.whl.metadata (2.5 kB)
Collecting mdurl~=0.1 (from markdown-it-py>=2.2.0->rich->keras>=3.0.0->tensorflow)
Using cached mdurl-0.1.2-py3-none-any.whl.metadata (1.6 kB)
Using cached matplotlib-3.10.7-cp312-cp312-macosx_10_13_x86_64.whl (8.3 MB)
Using cached scikit_learn-1.7.2-cp312-cp312-macosx_10_13_x86_64.whl (9.3 MB)
Using cached tensorflow-2.16.2-cp312-cp312-macosx_10_15_x86_64.whl (259.7 MB)
Using cached numpy-1.26.4-cp312-cp312-macosx_10_9_x86_64.whl (20.3 MB)
Using cached grpcio-1.76.0-cp312-cp312-macosx_11_0_universal2.whl (11.8 MB)
Using cached ml_dtypes-0.3.2-cp312-cp312-macosx_10_9_universal2.whl (393 kB)
Using cached protobuf-4.25.8-cp37-abi3-macosx_10_9_universal2.whl (394 kB)
Using cached requests-2.32.5-py3-none-any.whl (64 kB)
Using cached charset_normalizer-3.4.4-cp312-cp312-macosx_10_13_universal2.whl (208 kB)
Using cached idna-3.11-py3-none-any.whl (71 kB)
Using cached tensorboard-2.16.2-py3-none-any.whl (5.5 MB)
Using cached tensorboard_data_server-0.7.2-py3-none-macosx_10_9_x86_64.whl (4.8 MB)
Using cached typing_extensions-4.15.0-py3-none-any.whl (44 kB)
Using cached urllib3-2.5.0-py3-none-any.whl (129 kB)
Using cached absl_py-2.3.1-py3-none-any.whl (135 kB)
Using cached astunparse-1.6.3-py2.py3-none-any.whl (12 kB)
Using cached six-1.17.0-py2.py3-none-any.whl (11 kB)
Using cached wheel-0.45.1-py3-none-any.whl (72 kB)
Using cached certifi-2025.11.12-py3-none-any.whl (159 kB)
Using cached contourpy-1.3.3-cp312-cp312-macosx_10_13_x86_64.whl (293 kB)
Using cached cycler-0.12.1-py3-none-any.whl (8.3 kB)
Using cached flatbuffers-25.9.23-py2.py3-none-any.whl (30 kB)
Using cached fonttools-4.60.1-cp312-cp312-macosx_10_13_x86_64.whl (2.4 MB)
Using cached gast-0.6.0-py3-none-any.whl (21 kB)
Using cached google_pasta-0.2.0-py3-none-any.whl (57 kB)

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Using cached h5py-3.15.1-cp312-cp312-macosx_10_13_x86_64.whl (3.4 MB)
Using cached joblib-1.5.2-py3-none-any.whl (308 kB)
Using cached keras-3.12.0-py3-none-any.whl (1.5 MB)
Using cached kiwisolver-1.4.9-cp312-cp312-macosx_10_13_x86_64.whl (66 kB)
Using cached libclang-18.1.1-py2.py3-none-macosx_10_9_x86_64.whl (26.5 MB)
Using cached markdown-3.10-py3-none-any.whl (107 kB)
Using cached opt_einsum-3.4.0-py3-none-any.whl (71 kB)
Using cached packaging-25.0-py3-none-any.whl (66 kB)
Using cached pillow-12.0.0-cp312-cp312-macosx_10_13_x86_64.whl (5.2 MB)
Using cached pyparsing-3.2.5-py3-none-any.whl (113 kB)
Using cached python_dateutil-2.9.0.post0-py2.py3-none-any.whl (229 kB)
Using cached scipy-1.16.3-cp312-cp312-macosx_14_0_x86_64.whl (23.6 MB)
Using cached setuptools-80.9.0-py3-none-any.whl (1.2 MB)
Using cached termcolor-3.2.0-py3-none-any.whl (7.7 kB)
Using cached threadpoolctl-3.6.0-py3-none-any.whl (18 kB)
Using cached werkzeug-3.1.3-py3-none-any.whl (224 kB)
Using cached markupsafe-3.0.3-cp312-cp312-macosx_10_13_x86_64.whl (11 kB)
Using cached wrapt-2.0.1-cp312-cp312-macosx_10_13_x86_64.whl (61 kB)
Using cached namex-0.1.0-py3-none-any.whl (5.9 kB)
Using cached optree-0.18.0-cp312-cp312-macosx_10_13_x86_64.whl (369 kB)
Using cached rich-14.2.0-py3-none-any.whl (243 kB)
Using cached pygments-2.19.2-py3-none-any.whl (1.2 MB)
Using cached markdown_it_py-4.0.0-py3-none-any.whl (87 kB)
Using cached mdurl-0.1.2-py3-none-any.whl (10.0 kB)
Installing collected packages: namex, libclang, flatbuffers, wrapt, wheel, urllib3, ty
ping-extensions, threadpoolctl, termcolor, tensorboard-data-server, six, setuptools, p
yparsing, pygments, protobuf, pillow, packaging, opt-einsum, numpy, mdurl, MarkupSafe,
markdown, kiwisolver, joblib, idna, gast, fonttools, cycler, charset_normalizer, certi
fi, absl-py, werkzeug, scipy, requests, python-dateutil, optree, ml-dtypes, markdown-i
t-py, h5py, grpcio, google-pasta, contourpy, astunparse, tensorboard, scikit-learn, ri
ch, matplotlib, keras, tensorflow
Attempting uninstall: namex
  Found existing installation: namex 0.1.0
  Uninstalling namex-0.1.0:
    Successfully uninstalled namex-0.1.0
Attempting uninstall: libclang
  Found existing installation: libclang 18.1.1
  Uninstalling libclang-18.1.1:
    Successfully uninstalled libclang-18.1.1
Attempting uninstall: flatbuffers===== 1/49 [libclang]
  Found existing installation: flatbuffers 25.9.23===== 1/49 [libclang]
  Uninstalling flatbuffers-25.9.23:===== 1/49 [libclang]
    Successfully uninstalled flatbuffers-25.9.23===== 1/49 [libclang]
Attempting uninstall: wrapt===== 1/49 [libclang]
  Found existing installation: wrapt 2.0.1===== 1/49 [libclang]
  Uninstalling wrapt-2.0.1:===== 1/49 [libclang]
    Successfully uninstalled wrapt-2.0.1===== 1/49 [libclang]
Attempting uninstall: wheel===== 1/49 [libclang]
  Found existing installation: wheel 0.45.1===== 4/49 [wheel]
  Uninstalling wheel-0.45.1:===== 4/49 [wheel]
    Successfully uninstalled wheel-0.45.1===== 4/49 [wheel]
Attempting uninstall: urllib3===== 4/49 [wheel]
  Found existing installation: urllib3 2.5.0===== 4/49 [wheel]
  Uninstalling urllib3-2.5.0:===== 4/49 [wheel]
    Successfully uninstalled urllib3-2.5.0===== 4/49 [wheel]
Attempting uninstall: typing-extensions===== 5/49 [urllib3]
  Found existing installation: typing_extensions 4.15.0===== 5/49 [urllib3]
  Uninstalling typing_extensions-4.15.0:===== 5/49 [urllib3]
    Successfully uninstalled typing_extensions-4.15.0===== 6/49 [typing-exten
sions]
Attempting uninstall: threadpoolctl===== 6/49 [typing-extension
s]
  Found existing installation: threadpoolctl 3.6.0===== 6/49 [typing-extension
s]
  Uninstalling threadpoolctl-3.6.0:===== 6/49 [typing-extension
s]

```

```
Successfully uninstalled threadpoolctl-3.6.0 7/49 [threadpoolctl]
1]
Attempting uninstall: termcolor 7/49 [threadpoolctl]
Found existing installation: termcolor 3.2.0 7/49 [threadpoolctl]
Uninstalling termcolor-3.2.0: 7/49 [threadpoolctl]
Successfully uninstalled termcolor-3.2.0 7/49 [threadpoolctl]
Attempting uninstall: tensorboard-data-server 8/49 [termcolor]
Found existing installation: tensorboard-data-server 0.7.2 8/49 [termcolor]
Uninstalling tensorboard-data-server-0.7.2: 8/49 [termcolor]
Successfully uninstalled tensorboard-data-server-0.7.2 8/49 [termcolor]
Attempting uninstall: six 8/49 [termcolor]
Found existing installation: six 1.17.0 8/49 [termcolor]
Uninstalling six-1.17.0: 8/49 [termcolor]
Successfully uninstalled six-1.17.0 10/49 [six]
Attempting uninstall: setuptools 10/49 [six]
Found existing installation: setuptools 80.9.0 11/49 [setuptools]
Uninstalling setuptools-80.9.0: 11/49 [setuptools]
Successfully uninstalled setuptools-80.9.0 11/49 [setuptools]
Attempting uninstall: pyparsing 11/49 [setuptools]
Found existing installation: pyparsing 3.2.5 11/49 [setuptools]
Uninstalling pyparsing-3.2.5: 11/49 [setuptools]
Successfully uninstalled pyparsing-3.2.5 11/49 [setuptools]
Attempting uninstall: pygments 12/49 [pyparsing]
Found existing installation: Pygments 2.19.2 12/49 [pyparsing]
Uninstalling Pygments-2.19.2: 12/49 [pyparsing]
Successfully uninstalled Pygments-2.19.2 12/49 [pyparsing]
Attempting uninstall: protobuf 13/49 [pygments]
Found existing installation: protobuf 4.25.8 13/49 [pygments]
Uninstalling protobuf-4.25.8: 13/49 [pygments]
Successfully uninstalled protobuf-4.25.8 13/49 [pygments]
Attempting uninstall: pillow 14/49 [protobuf]
Found existing installation: pillow 12.0.0 14/49 [protobuf]
Uninstalling pillow-12.0.0: 14/49 [protobuf]
Successfully uninstalled pillow-12.0.0 14/49 [protobuf]
Attempting uninstall: packaging 15/49 [pillow]
Found existing installation: packaging 25.0 15/49 [pillow]
Uninstalling packaging-25.0: 15/49 [pillow]
Successfully uninstalled packaging-25.0 15/49 [pillow]
Attempting uninstall: opt-einsum 16/49 [packaging]
Found existing installation: opt_einsum 3.4.0 16/49 [packaging]
Uninstalling opt_einsum-3.4.0: 16/49 [packaging]
Successfully uninstalled opt_einsum-3.4.0 16/49 [packaging]
Attempting uninstall: numpy 16/49 [packaging]
Found existing installation: numpy 2.3.4 18/49 [numpy]
Uninstalling numpy-2.3.4: 18/49 [numpy]
Successfully uninstalled numpy-2.3.4 18/49 [numpy]
Attempting uninstall: mdurl 18/49 [numpy]
Found existing installation: mdurl 0.1.2 18/49 [numpy]
Uninstalling mdurl-0.1.2: 18/49 [numpy]
Successfully uninstalled mdurl-0.1.2 18/49 [numpy]
Attempting uninstall: MarkupSafe 18/49 [numpy]
Found existing installation: MarkupSafe 3.0.3 18/49 [numpy]
Uninstalling MarkupSafe-3.0.3: 18/49 [numpy]
Successfully uninstalled MarkupSafe-3.0.3 18/49 [numpy]
Attempting uninstall: markdown 20/49 [MarkupSafe]
Found existing installation: Markdown 3.10 20/49 [MarkupSafe]
Uninstalling Markdown-3.10: 20/49 [MarkupSafe]
Successfully uninstalled Markdown-3.10 20/49 [MarkupSafe]
Attempting uninstall: kiwisolver 20/49 [MarkupSafe]
Found existing installation: kiwisolver 1.4.9 22/49 [kiwisolver]
Uninstalling kiwisolver-1.4.9: 22/49 [kiwisolver]
Successfully uninstalled kiwisolver-1.4.9 22/49 [kiwisolver]
Attempting uninstall: joblib 22/49 [kiwisolver]
Found existing installation: joblib 1.5.2 22/49 [kiwisolver]
Uninstalling joblib-1.5.2: 22/49 [kiwisolver]
Successfully uninstalled joblib-1.5.2 22/49 [kiwisolver]
```

```
Attempting uninstall: idna0m----- 23/49 [joblib]
Found existing installation: idna 3.11----- 23/49 [joblib]
Uninstalling idna-3.11:[91m----- 23/49 [joblib]
Successfully uninstalled idna-3.11m----- 23/49 [joblib]
Attempting uninstall: gast0m----- 24/49 [idna]
Found existing installation: gast 0.6.0----- 24/49 [idna]
Uninstalling gast-0.6.0:[91m----- 24/49 [idna]
Successfully uninstalled gast-0.6.0m----- 24/49 [idna]
Attempting uninstall: fonttools----- 24/49 [idna]
Found existing installation: fonttools 4.60.1----- 24/49 [idna]
Uninstalling fonttools-4.60.1:[0m----- 24/49 [idna]
Successfully uninstalled fonttools-4.60.1----- 24/49 [idna]
Attempting uninstall: cycler0m----- 26/49 [fonttools]
Found existing installation: cycler 0.12.1----- 26/49 [fonttools]
Uninstalling cycler-0.12.1:90m----- 26/49 [fonttools]
Successfully uninstalled cycler-0.12.1----- 26/49 [fonttools]
Attempting uninstall: charset_normalizer0m----- 26/49 [fonttools]
Found existing installation: charset-normalizer 3.4.4----- 26/49 [fonttools]
Uninstalling charset-normalizer-3.4.4:0m----- 26/49 [fonttools]
Successfully uninstalled charset-normalizer-3.4.4----- 26/49 [fonttools]
Attempting uninstall: certifi0m----- 28/49 [charset_normalizer]
Found existing installation: certifi 2025.11.12----- 28/49 [charset_normaliz
er]
Uninstalling certifi-2025.11.12:----- 28/49 [charset_normalizer]
Successfully uninstalled certifi-2025.11.12----- 28/49 [charset_normaliz
er]
Attempting uninstall: absl-py[91m----- 28/49 [charset_normalizer]
Found existing installation: absl-py 2.3.1----- 28/49 [charset_normaliz
er]
Uninstalling absl-py-2.3.1:[91m----- 28/49 [charset_normalizer]
Successfully uninstalled absl-py-2.3.1m----- 28/49 [charset_normaliz
er]
Attempting uninstall: werkzeug----- 30/49 [absl-py]alizer]
Found existing installation: Werkzeug 3.1.3----- 30/49 [absl-py]
Uninstalling Werkzeug-3.1.3:----- 30/49 [absl-py]
Successfully uninstalled Werkzeug-3.1.30m----- 30/49 [absl-py]
Attempting uninstall: scipy----- 31/49 [werkzeug]
Found existing installation: scipy 1.16.3[0m----- 32/49 [scipy]
Uninstalling scipy-1.16.3:----- 32/49 [scipy]
Successfully uninstalled scipy-1.16.3----- 32/49 [scipy]
Attempting uninstall: requests----- 32/49 [scipy]
Found existing installation: requests 2.32.5m----- 32/49 [scipy]
Uninstalling requests-2.32.5:m----- 32/49 [scipy]
Successfully uninstalled requests-2.32.590m----- 32/49 [scipy]
Attempting uninstall: python-dateutil[91m----- 33/49 [requests]
Found existing installation: python-dateutil 2.9.0.post0----- 33/49 [requests]
Uninstalling python-dateutil-2.9.0.post0:[90m----- 33/49 [requests]
Successfully uninstalled python-dateutil-2.9.0.post0----- 33/49 [requests]
Attempting uninstall: optree----- 33/49 [requests]
Found existing installation: optree 0.18.090m----- 33/49 [requests]
Uninstalling optree-0.18.0:[0m----- 33/49 [requests]
Successfully uninstalled optree-0.18.0----- 33/49 [requests]
Attempting uninstall: ml-dtypes----- 35/49 [optree]
Found existing installation: ml-dtypes 0.3.290m----- 35/49 [optree]
Uninstalling ml-dtypes-0.3.2:[0m----- 35/49 [optree]
Successfully uninstalled ml-dtypes-0.3.2----- 35/49 [optree]
Attempting uninstall: markdown-it-py[91m----- 35/49 [optree]
Found existing installation: markdown-it-py 4.0.0----- 35/49 [optree]
Uninstalling markdown-it-py-4.0.0:91m----- 35/49 [optree]
Successfully uninstalled markdown-it-py-4.0.0----- 35/49 [optree]
Attempting uninstall: h5py----- 37/49 [markdown-it-py]
Found existing installation: h5py 3.15.1----- 37/49 [markdown-it-py]
Uninstalling h5py-3.15.1:----- 37/49 [markdown-it-py]
Successfully uninstalled h5py-3.15.1m----- 37/49 [markdown-it-py]
Attempting uninstall: grpcio----- 38/49 [h5py]it-py]
Found existing installation: grpcio 1.76.0[0m----- 38/49 [h5py]
```

```

Uninstalling grpcio-1.76.0:————— 38/49 [h5py]
Successfully uninstalled grpcio-1.76.0————— 38/49 [h5py]
Attempting uninstall: google-pasta————— 39/49 [grpcio]
Found existing installation: google-pasta 0.2.090m————— 39/49 [grpcio]
Uninstalling google-pasta-0.2.0:[0m————— 39/49 [grpcio]
Successfully uninstalled google-pasta-0.2.0————— 39/49 [grpcio]
Attempting uninstall: contourpy————— 40/49 [google-pasta]
Found existing installation: contourpy 1.3.30m————— 40/49 [google-pasta]
Uninstalling contourpy-1.3.3:————— 40/49 [google-pasta]
Successfully uninstalled contourpy-1.3.3————— 40/49 [google-pasta]
Attempting uninstall: astunparse————— 40/49 [google-pasta]
Found existing installation: astunparse 1.6.3m————— 40/49 [google-pasta]
Uninstalling astunparse-1.6.3:————— 40/49 [google-pasta]
Successfully uninstalled astunparse-1.6.3[0m————— 40/49 [google-pasta]
Attempting uninstall: tensorboard————— 40/49 [google-pasta]
Found existing installation: tensorboard 2.16.2[90m————— 40/49 [google-pasta]
Uninstalling tensorboard-2.16.2:————— 43/49 [tensorboard]
Successfully uninstalled tensorboard-2.16.2————— 43/49 [tensorboard]
Attempting uninstall: scikit-learn————— 43/49 [tensorboard]
Found existing installation: scikit-learn 1.7.20m————— 43/49 [tensorboard]
Uninstalling scikit-learn-1.7.2:————— 44/49 [scikit-learn]
Successfully uninstalled scikit-learn-1.7.2————— 44/49 [scikit-learn]
Attempting uninstall: rich————— 44/49 [scikit-learn]
Found existing installation: rich 14.2.0[91m————— 44/49 [scikit-learn]
Uninstalling rich-14.2.0:————— 44/49 [scikit-learn]
Successfully uninstalled rich-14.2.0m————— 44/49 [scikit-learn]
Attempting uninstall: matplotlib————— 45/49 [rich]
Found existing installation: matplotlib 3.10.7————— 45/49 [rich]
Uninstalling matplotlib-3.10.7:————— 45/49 [rich]
Successfully uninstalled matplotlib-3.10.7m————— 46/49 [matplotlib]
Attempting uninstall: keras————— 46/49 [matplotlib]
Found existing installation: keras 3.12.0————— 46/49 [matplotlib]
Uninstalling keras-3.12.0:————— 47/49 [keras]
Successfully uninstalled keras-3.12.0[0m————— 47/49 [keras]
Attempting uninstall: tensorflow————— 47/49 [keras]
Found existing installation: tensorflow 2.16.2m————— 47/49 [keras]
Uninstalling tensorflow-2.16.2:————— 48/49 [tensorflow]
Successfully uninstalled tensorflow-2.16.2[0m————— 48/49 [tensorflow]
————— 49/49 [tensorflow]nsorflow]
Successfully installed MarkupSafe-3.0.3 absl-py-2.3.1 astunparse-1.6.3 certifi-2025.1
1.12 charset_normalizer-3.4.4 contourpy-1.3.3 cycler-0.12.1 flatbuffers-25.9.23 fontto
ols-4.60.1 gast-0.6.0 google-pasta-0.2.0 grpcio-1.76.0 h5py-3.15.1 idna-3.11 joblib-1.
5.2 keras-3.12.0 kiwisolver-1.4.9 libclang-18.1.1 markdown-3.10 markdown-it-py-4.0.0 m
atplotlib-3.10.7 mdurl-0.1.2 ml-dtypes-0.3.2 namex-0.1.0 numpy-1.26.4 opt-einsum-3.4.0
optree-0.18.0 packaging-25.0 pillow-12.0.0 protobuf-4.25.8 pygments-2.19.2 pyparsing-
3.2.5 python-dateutil-2.9.0.post0 requests-2.32.5 rich-14.2.0 scikit-learn-1.7.2 scipy
-1.16.3 setuptools-80.9.0 six-1.17.0 tensorboard-2.16.2 tensorboard-data-server-0.7.2
tensorflow-2.16.2 termcolor-3.2.0 threadpoolctl-3.6.0 typing-extensions-4.15.0 urllib3
-2.5.0 werkzeug-3.1.3 wheel-0.45.1 wrapt-2.0.1

```

```

In [17]: import numpy as np
import matplotlib.pyplot as plt
from sklearn.model_selection import train_test_split
import tensorflow as tf

print("NumPy:", np.__version__)
print("TF:", tf.__version__)

```

NumPy: 1.26.4

TF: 2.16.2

```

In [18]: !pip install --force-reinstall numpy

```

Collecting numpy

Using cached numpy-2.3.4-cp312-cp312-macosx_14_0_x86_64.whl.metadata (62 kB)

Using cached numpy-2.3.4-cp312-cp312-macosx_14_0_x86_64.whl (6.6 MB)

Installing collected packages: numpy

Attempting uninstall: numpy

Found existing installation: numpy 1.26.4

Uninstalling numpy-1.26.4:

Successfully uninstalled numpy-1.26.4

ERROR: pip's dependency resolver does not currently take into account all the packages that are installed. This behaviour is the source of the following dependency conflict s.

gensim 4.3.3 requires numpy<2.0,>=1.18.5, but you have numpy 2.3.4 which is incompatible.

scipy 1.13.1 requires numpy<2.3,>=1.22.4, but you have numpy 2.3.4 which is incompatible.

contourpy 1.2.0 requires numpy<2.0,>=1.20, but you have numpy 2.3.4 which is incompatible.

tensorflow 2.16.2 requires numpy<2.0.0,>=1.26.0; python_version >= "3.12", but you have numpy 2.3.4 which is incompatible.

numba 0.60.0 requires numpy<2.1,>=1.22, but you have numpy 2.3.4 which is incompatible.

Successfully installed numpy-2.3.4

Eye Disease Classification using CNN

Student: *Sultan Abdulrahim Hassan*

Course: Image Processing and Natural Language Processing

Date: 2025-11-16

This notebook implements the required project steps on the **eye disease dataset** provided by the instructor, with four classes:

- cataract
- diabetic_retinopathy
- glaucoma
- normal

It follows these stages:

1. Load the image dataset.
2. Split into **train / validation / test**.
3. Apply **data augmentation**.
4. Train and test a **CNN** model.
5. Export this notebook to **PDF** for submission.

1) Environment Setup

```
In [19]: !pip install -U pip
!pip install tensorflow matplotlib scikit-learn

import os, sys, math, random, pathlib
import numpy as np
import matplotlib.pyplot as plt

from sklearn.model_selection import train_test_split
from sklearn.metrics import classification_report, confusion_matrix

import tensorflow as tf
```

```
from tensorflow import keras
from tensorflow.keras import layers

print("Python:", sys.version)
print("TensorFlow:", tf.__version__)
print("GPU devices:", tf.config.list_physical_devices('GPU'))

DATASET_DIR = pathlib.Path.cwd()
print("DATASET_DIR:", DATASET_DIR)

expected_classes = ["cataract", "diabetic_retinopathy", "glaucoma", "normal"]
print("Expected subfolders:")
for cls in expected_classes:
    print(f" {cls}: {(DATASET_DIR / cls).exists()}")
```

Requirement already satisfied: pip in /opt/anaconda3/lib/python3.12/site-packages (25.3)

Requirement already satisfied: tensorflow in /opt/anaconda3/lib/python3.12/site-packages (2.16.2)

Requirement already satisfied: matplotlib in /opt/anaconda3/lib/python3.12/site-packages (3.9.2)

Requirement already satisfied: scikit-learn in /opt/anaconda3/lib/python3.12/site-packages (1.5.1)

Requirement already satisfied: absl-py>=1.0.0 in /opt/anaconda3/lib/python3.12/site-packages (from tensorflow) (2.3.1)

Requirement already satisfied: astunparse>=1.6.0 in /opt/anaconda3/lib/python3.12/site-packages (from tensorflow) (1.6.3)

Requirement already satisfied: flatbuffers>=23.5.26 in /opt/anaconda3/lib/python3.12/site-packages (from tensorflow) (25.9.23)

Requirement already satisfied: gast!=0.5.0,!0.5.1,!0.5.2,>=0.2.1 in /opt/anaconda3/lib/python3.12/site-packages (from tensorflow) (0.6.0)

Requirement already satisfied: google-pasta>=0.1.1 in /opt/anaconda3/lib/python3.12/site-packages (from tensorflow) (0.2.0)

Requirement already satisfied: h5py>=3.10.0 in /opt/anaconda3/lib/python3.12/site-packages (from tensorflow) (3.11.0)

Requirement already satisfied: libclang>=13.0.0 in /opt/anaconda3/lib/python3.12/site-packages (from tensorflow) (18.1.1)

Requirement already satisfied: ml-dtypes~=0.3.1 in /opt/anaconda3/lib/python3.12/site-packages (from tensorflow) (0.3.2)

Requirement already satisfied: opt-einsum>=2.3.2 in /opt/anaconda3/lib/python3.12/site-packages (from tensorflow) (3.4.0)

Requirement already satisfied: packaging in /opt/anaconda3/lib/python3.12/site-packages (from tensorflow) (24.1)

Requirement already satisfied: protobuf!=4.21.0,!4.21.1,!4.21.2,!4.21.3,!4.21.4,!4.21.5,<5.0.0dev,>=3.20.3 in /opt/anaconda3/lib/python3.12/site-packages (from tensorflow) (4.25.3)

Requirement already satisfied: requests<3,>=2.21.0 in /opt/anaconda3/lib/python3.12/site-packages (from tensorflow) (2.32.3)

Requirement already satisfied: setuptools in /opt/anaconda3/lib/python3.12/site-packages (from tensorflow) (75.1.0)

Requirement already satisfied: six>=1.12.0 in /opt/anaconda3/lib/python3.12/site-packages (from tensorflow) (1.16.0)

Requirement already satisfied: termcolor>=1.1.0 in /opt/anaconda3/lib/python3.12/site-packages (from tensorflow) (3.2.0)

Requirement already satisfied: typing-extensions>=3.6.6 in /opt/anaconda3/lib/python3.12/site-packages (from tensorflow) (4.15.0)

Requirement already satisfied: wrapt>=1.11.0 in /opt/anaconda3/lib/python3.12/site-packages (from tensorflow) (1.14.1)

Requirement already satisfied: grpcio<2.0,>=1.24.3 in /opt/anaconda3/lib/python3.12/site-packages (from tensorflow) (1.76.0)

Requirement already satisfied: tensorboard<2.17,>=2.16 in /opt/anaconda3/lib/python3.12/site-packages (from tensorflow) (2.16.2)

Requirement already satisfied: keras>=3.0.0 in /opt/anaconda3/lib/python3.12/site-packages (from tensorflow) (3.12.0)

Collecting numpy<2.0.0,>=1.26.0 (from tensorflow)

Using cached numpy-1.26.4-cp312-cp312-macosx_10_9_x86_64.whl.metadata (61 kB)

Requirement already satisfied: charset-normalizer<4,>=2 in /opt/anaconda3/lib/python3.12/site-packages (from requests<3,>=2.21.0->tensorflow) (3.3.2)

Requirement already satisfied: idna<4,>=2.5 in /opt/anaconda3/lib/python3.12/site-packages (from requests<3,>=2.21.0->tensorflow) (3.7)

Requirement already satisfied: urllib3<3,>=1.21.1 in /opt/anaconda3/lib/python3.12/site-packages (from requests<3,>=2.21.0->tensorflow) (2.2.3)

Requirement already satisfied: certifi>=2017.4.17 in /opt/anaconda3/lib/python3.12/site-packages (from requests<3,>=2.21.0->tensorflow) (2025.8.3)

Requirement already satisfied: markdown>=2.6.8 in /opt/anaconda3/lib/python3.12/site-packages (from tensorboard<2.17,>=2.16->tensorflow) (3.4.1)

Requirement already satisfied: tensorboard-data-server<0.8.0,>=0.7.0 in /opt/anaconda3/lib/python3.12/site-packages (from tensorboard<2.17,>=2.16->tensorflow) (0.7.2)

Requirement already satisfied: werkzeug>=1.0.1 in /opt/anaconda3/lib/python3.12/site-packages (from tensorboard<2.17,>=2.16->tensorflow) (3.0.3)

Requirement already satisfied: contourpy>=1.0.1 in /opt/anaconda3/lib/python3.12/site-

packages (from matplotlib) (1.2.0)
 Requirement already satisfied: cycler>=0.10 in /opt/anaconda3/lib/python3.12/site-packages (from matplotlib) (0.11.0)
 Requirement already satisfied: fonttools>=4.22.0 in /opt/anaconda3/lib/python3.12/site-packages (from matplotlib) (4.51.0)
 Requirement already satisfied: kiwisolver>=1.3.1 in /opt/anaconda3/lib/python3.12/site-packages (from matplotlib) (1.4.4)
 Requirement already satisfied: pillow>=8 in /opt/anaconda3/lib/python3.12/site-packages (from matplotlib) (10.4.0)
 Requirement already satisfied: pyparsing>=2.3.1 in /opt/anaconda3/lib/python3.12/site-packages (from matplotlib) (3.1.2)
 Requirement already satisfied: python-dateutil>=2.7 in /opt/anaconda3/lib/python3.12/site-packages (from matplotlib) (2.9.0.post0)
 Requirement already satisfied: scipy>=1.6.0 in /opt/anaconda3/lib/python3.12/site-packages (from scikit-learn) (1.13.1)
 Requirement already satisfied: joblib>=1.2.0 in /opt/anaconda3/lib/python3.12/site-packages (from scikit-learn) (1.4.2)
 Requirement already satisfied: threadpoolctl>=3.1.0 in /opt/anaconda3/lib/python3.12/site-packages (from scikit-learn) (3.5.0)
 Requirement already satisfied: wheel<1.0,>=0.23.0 in /opt/anaconda3/lib/python3.12/site-packages (from astunparse>=1.6.0->tensorflow) (0.44.0)
 Requirement already satisfied: rich in /opt/anaconda3/lib/python3.12/site-packages (from keras>=3.0.0->tensorflow) (13.7.1)
 Requirement already satisfied: namex in /opt/anaconda3/lib/python3.12/site-packages (from keras>=3.0.0->tensorflow) (0.1.0)
 Requirement already satisfied: optree in /opt/anaconda3/lib/python3.12/site-packages (from keras>=3.0.0->tensorflow) (0.18.0)
 Requirement already satisfied: MarkupSafe>=2.1.1 in /opt/anaconda3/lib/python3.12/site-packages (from werkzeug>=1.0.1->tensorboard<2.17,>=2.16->tensorflow) (2.1.3)
 Requirement already satisfied: markdown-it-py>=2.2.0 in /opt/anaconda3/lib/python3.12/site-packages (from rich->keras>=3.0.0->tensorflow) (2.2.0)
 Requirement already satisfied: pygments<3.0.0,>=2.13.0 in /opt/anaconda3/lib/python3.12/site-packages (from rich->keras>=3.0.0->tensorflow) (2.15.1)
 Requirement already satisfied: mdurl~=0.1 in /opt/anaconda3/lib/python3.12/site-packages (from markdown-it-py>=2.2.0->rich->keras>=3.0.0->tensorflow) (0.1.0)
 Using cached numpy-1.26.4-cp312-cp312-macosx_10_9_x86_64.whl (20.3 MB)
 Installing collected packages: numpy
 Attempting uninstall: numpy
 Found existing installation: numpy 2.3.4
 Uninstalling numpy-2.3.4:
 Successfully uninstalled numpy-2.3.4
 Successfully installed numpy-1.26.4
 Python: 3.12.11 | packaged by Anaconda, Inc. | (main, Jun 5 2025, 08:06:15) [Clang 14.0.6]
 TensorFlow: 2.16.2
 GPU devices: []
 DATASET_DIR: /Users/jkis/Desktop/Image Processing/dataset
 Expected subfolders:
 cataract: True
 diabetic_retinopathy: True
 glaucoma: True
 normal: True

2) Load Image Paths and Labels

```

In [20]: # Collect image filepaths and labels from the four folders.
class_names = []
filepaths = []
labels = []

for cls in sorted(expected_classes):
    cls_dir = DATASET_DIR / cls
    if cls_dir.is_dir():
        class_names.append(cls)
  
```

```

        for ext in ("*.jpg", "*.jpeg", "*.png", "*.bmp"):
            for fp in cls_dir.glob(ext):
                filepaths.append(str(fp))
                labels.append(cls)
    else:
        print(f"Warning: folder not found -> {cls_dir}")

filepaths = np.array(filepaths)
labels = np.array(labels)

print("Detected class names:", class_names)
print("Total images found:", len(filepaths))

assert len(filepaths) > 0, "No images found. Check DATASET_DIR and folder structure."

```

Detected class names: ['cataract', 'diabetic_retinopathy', 'glaucoma', 'normal']
 Total images found: 4217

3) Split Dataset into Train / Validation / Test

In [21]: *# We create an 80 / 10 / 10 split using train_test_split with stratification.*

```

X_temp, X_test, y_temp, y_test = train_test_split(
    filepaths, labels, test_size=0.1, random_state=42, stratify=labels
)
X_train, X_val, y_train, y_val = train_test_split(
    X_temp, y_temp, test_size=0.1111, random_state=42, stratify=y_temp
) # 0.1111 of 90% ≈ 10%

print("Train size:", len(X_train))
print("Validation size:", len(X_val))
print("Test size:", len(X_test))

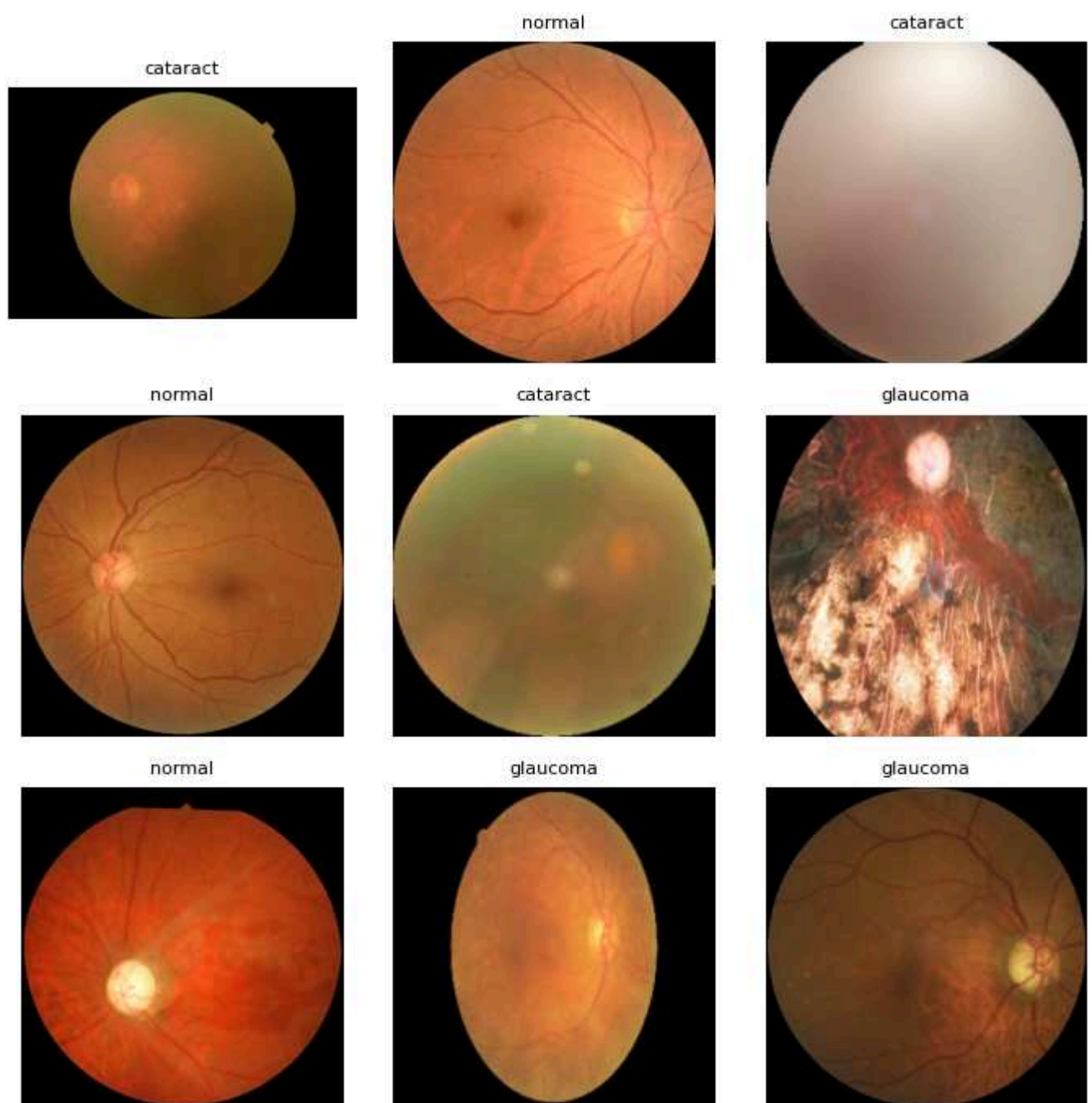
# Quick visualization of some training images
def load_image_for_plot(path):
    img_raw = tf.io.read_file(path)
    img = tf.image.decode_image(img_raw, channels=3)
    img.set_shape([None, None, 3])
    return img.numpy()

def show_grid(paths, labels, n=9):
    plt.figure(figsize=(7,7))
    idx = np.random.choice(len(paths), size=n, replace=False)
    side = int(math.sqrt(n))
    for i, ix in enumerate(idx):
        plt.subplot(side, side, i+1)
        img = load_image_for_plot(paths[ix])
        plt.imshow(img)
        plt.title(labels[ix], fontsize=8)
        plt.axis("off")
    plt.tight_layout()
    plt.show()

show_grid(X_train, y_train, n=9)

```

Train size: 3373
 Validation size: 422
 Test size: 422



4) Data Pipeline and Augmentation

```
In [27]: IMG_SIZE = (224, 224)
BATCH_SIZE = 16

import numpy as np
import tensorflow as tf
from tensorflow import keras
from tensorflow.keras import layers

class_names = sorted(list(set(labels)))
cls_to_idx = {c: i for i, c in enumerate(class_names)}
idx_to_cls = {i: c for c, i in cls_to_idx.items()}

print("Class mapping:", cls_to_idx)

data_augmentation = keras.Sequential([
    layers.RandomFlip("horizontal"),
    layers.RandomRotation(0.1),
    layers.RandomZoom(0.1),
    layers.RandomTranslation(0.1, 0.1),
], name="data_augmentation")
```

```

def load_and_preprocess(path):
    img_raw = tf.io.read_file(path)
    img = tf.image.decode_image(img_raw, channels=3, expand_animations=False)
    img.set_shape([None, None, 3])
    img = tf.image.resize(img, IMG_SIZE)
    img = tf.cast(img, tf.float32) / 255.0
    return img

def paths_to_array(paths, labels_arr):
    n = len(paths)
    X = np.zeros((n, IMG_SIZE[0], IMG_SIZE[1], 3), dtype=np.float32)
    y = np.zeros((n,), dtype=np.int32)
    for i, (p, lab) in enumerate(zip(paths, labels_arr)):
        img = load_and_preprocess(p)
        X[i] = img.numpy()
        y[i] = cls_to_idx[lab]
        if (i+1) % 200 == 0:
            print(f"Loaded {i+1}/{n} images...")
    return X, y

X_train_arr, y_train_arr = paths_to_array(X_train, y_train)
X_val_arr, y_val_arr = paths_to_array(X_val, y_val)
X_test_arr, y_test_arr = paths_to_array(X_test, y_test)

print("Train:", X_train_arr.shape, y_train_arr.shape)
print("Val: ", X_val_arr.shape, y_val_arr.shape)
print("Test: ", X_test_arr.shape, y_test_arr.shape)

```

```

Class mapping: {'cataract': 0, 'diabetic_retinopathy': 1, 'glaucoma': 2, 'normal': 3}
Loaded 200/3373 images...
Loaded 400/3373 images...
Loaded 600/3373 images...
Loaded 800/3373 images...
Loaded 1000/3373 images...
Loaded 1200/3373 images...
Loaded 1400/3373 images...
Loaded 1600/3373 images...
Loaded 1800/3373 images...
Loaded 2000/3373 images...
Loaded 2200/3373 images...
Loaded 2400/3373 images...
Loaded 2600/3373 images...
Loaded 2800/3373 images...
Loaded 3000/3373 images...
Loaded 3200/3373 images...
Loaded 200/422 images...
Loaded 400/422 images...
Loaded 200/422 images...
Loaded 400/422 images...
Train: (3373, 224, 224, 3) (3373,)
Val:  (422, 224, 224, 3) (422,)
Test: (422, 224, 224, 3) (422,)

```

5) Build the CNN Model

```

In [28]: def build_cnn(input_shape=(224, 224, 3), num_classes=4):
    inputs = keras.Input(shape=input_shape)
    x = data_augmentation(inputs)

    x = layers.Conv2D(32, 3, padding="same", activation="relu")(x)
    x = layers.Conv2D(32, 3, padding="same", activation="relu")(x)
    x = layers.MaxPooling2D()(x)
    x = layers.Dropout(0.25)(x)

```

```

x = layers.Conv2D(64, 3, padding="same", activation="relu")(x)
x = layers.Conv2D(64, 3, padding="same", activation="relu")(x)
x = layers.MaxPooling2D()(x)
x = layers.Dropout(0.25)(x)

x = layers.Conv2D(128, 3, padding="same", activation="relu")(x)
x = layers.Conv2D(128, 3, padding="same", activation="relu")(x)
x = layers.GlobalAveragePooling2D()(x)
x = layers.Dropout(0.3)(x)

x = layers.Dense(128, activation="relu")(x)
outputs = layers.Dense(num_classes, activation="softmax")(x)

model = keras.Model(inputs, outputs, name="eye_disease_cnn")
return model

num_classes = len(class_names)
model = build_cnn(num_classes=num_classes)
model.compile(
    optimizer=keras.optimizers.Adam(learning_rate=1e-3),
    loss="sparse_categorical_crossentropy",
    metrics=["accuracy"]
)

model.summary()

```

Model: "eye_disease_cnn"

Layer (type)	Output Shape	Param #
input_layer_1 (InputLayer)	(None, 224, 224, 3)	0
data_augmentation (Sequential)	(None, 224, 224, 3)	0
conv2d_6 (Conv2D)	(None, 224, 224, 32)	896
conv2d_7 (Conv2D)	(None, 224, 224, 32)	9,248
max_pooling2d_2 (MaxPooling2D)	(None, 112, 112, 32)	0
dropout_3 (Dropout)	(None, 112, 112, 32)	0
conv2d_8 (Conv2D)	(None, 112, 112, 64)	18,496
conv2d_9 (Conv2D)	(None, 112, 112, 64)	36,928
max_pooling2d_3 (MaxPooling2D)	(None, 56, 56, 64)	0
dropout_4 (Dropout)	(None, 56, 56, 64)	0
conv2d_10 (Conv2D)	(None, 56, 56, 128)	73,856
conv2d_11 (Conv2D)	(None, 56, 56, 128)	147,584
global_average_pooling2d_1 (GlobalAveragePooling2D)	(None, 128)	0
dropout_5 (Dropout)	(None, 128)	0
dense_2 (Dense)	(None, 128)	16,512
dense_3 (Dense)	(None, 4)	516

Total params: 304,036 (1.16 MB)

Trainable params: 304,036 (1.16 MB)

Non-trainable params: 0 (0.00 B)

6) Train the Model

```
In [29]: EPOCHS = 15

callbacks = [
    keras.callbacks.EarlyStopping(monitor="val_accuracy", patience=3, restore_best_weights=True),
    keras.callbacks.ReduceLROnPlateau(monitor="val_loss", factor=0.5, patience=2, min_lr=1e-6),
    keras.callbacks.ModelCheckpoint("eye_disease_cnn_best.keras",
                                    monitor="val_accuracy", save_best_only=True)
]

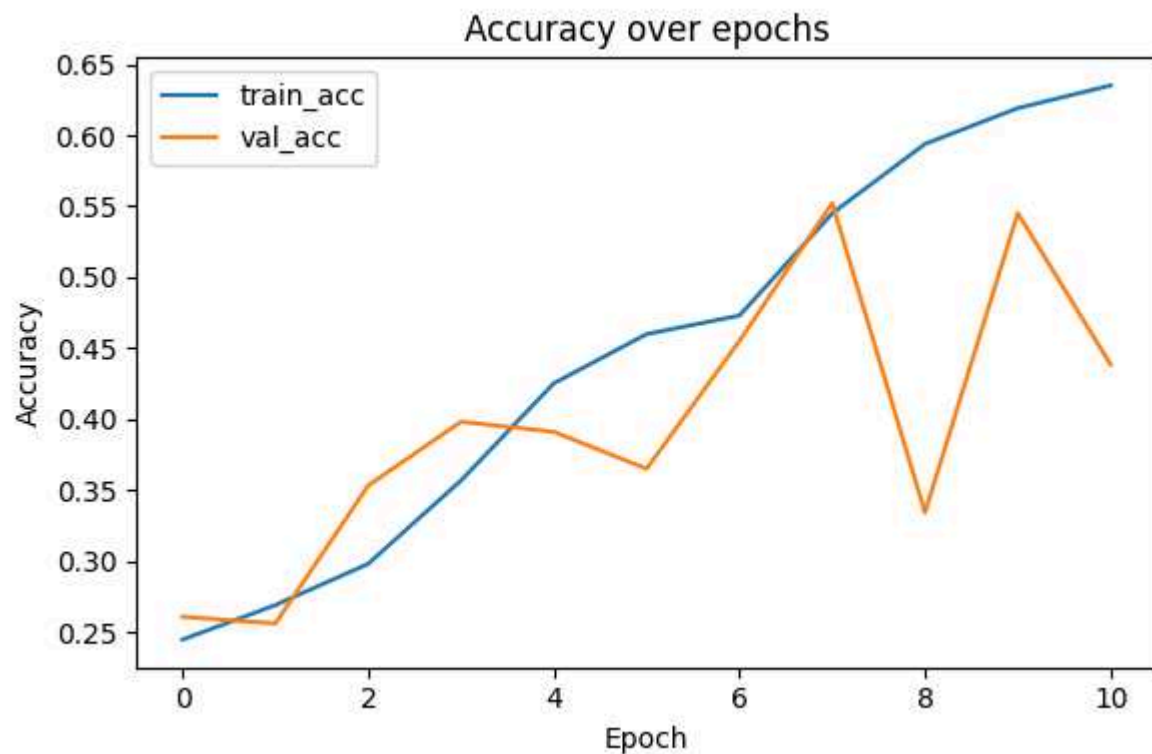
history = model.fit(
    X_train_arr, y_train_arr,
    validation_data=(X_val_arr, y_val_arr),
    epochs=EPOCHS,
    batch_size=BATCH_SIZE,
    callbacks=callbacks,
    verbose=1
)

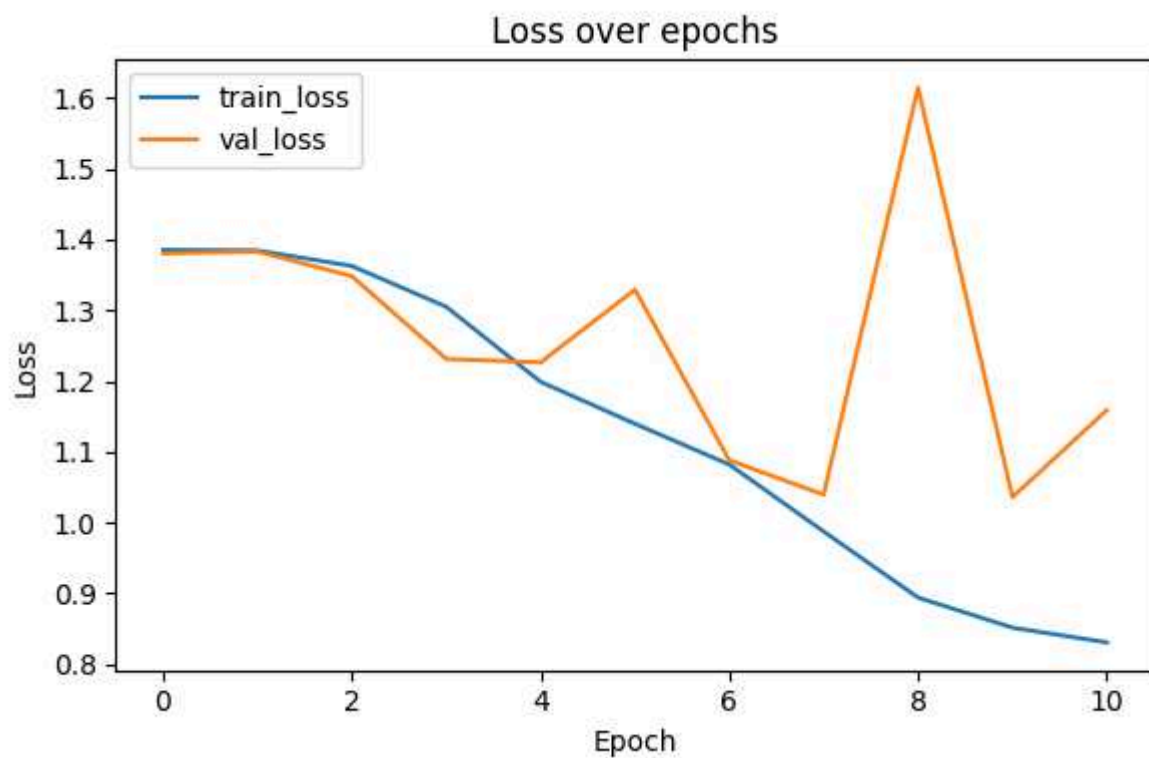
def plot_history(h):
    plt.figure(figsize=(6,4))
    plt.plot(h.history["accuracy"], label="train_acc")
    plt.plot(h.history["val_accuracy"], label="val_acc")
    plt.xlabel("Epoch")
    plt.ylabel("Accuracy")
    plt.title("Accuracy over epochs")
    plt.legend()
    plt.tight_layout()
    plt.show()

    plt.figure(figsize=(6,4))
    plt.plot(h.history["loss"], label="train_loss")
    plt.plot(h.history["val_loss"], label="val_loss")
    plt.xlabel("Epoch")
    plt.ylabel("Loss")
    plt.title("Loss over epochs")
    plt.legend()
    plt.tight_layout()
    plt.show()

plot_history(history)
```

Epoch 1/15
211/211 ————— 421s 2s/step - accuracy: 0.2446 - loss: 1.3852 - val_accuracy: 0.2607 - val_loss: 1.3802 - learning_rate: 0.0010
Epoch 2/15
211/211 ————— 366s 2s/step - accuracy: 0.2689 - loss: 1.3843 - val_accuracy: 0.2559 - val_loss: 1.3827 - learning_rate: 0.0010
Epoch 3/15
211/211 ————— 343s 2s/step - accuracy: 0.2980 - loss: 1.3625 - val_accuracy: 0.3531 - val_loss: 1.3481 - learning_rate: 0.0010
Epoch 4/15
211/211 ————— 350s 2s/step - accuracy: 0.3567 - loss: 1.3049 - val_accuracy: 0.3981 - val_loss: 1.2312 - learning_rate: 0.0010
Epoch 5/15
211/211 ————— 351s 2s/step - accuracy: 0.4251 - loss: 1.1989 - val_accuracy: 0.3910 - val_loss: 1.2263 - learning_rate: 0.0010
Epoch 6/15
211/211 ————— 351s 2s/step - accuracy: 0.4598 - loss: 1.1396 - val_accuracy: 0.3649 - val_loss: 1.3290 - learning_rate: 0.0010
Epoch 7/15
211/211 ————— 351s 2s/step - accuracy: 0.4729 - loss: 1.0820 - val_accuracy: 0.4550 - val_loss: 1.0880 - learning_rate: 0.0010
Epoch 8/15
211/211 ————— 340s 2s/step - accuracy: 0.5449 - loss: 0.9875 - val_accuracy: 0.5521 - val_loss: 1.0395 - learning_rate: 0.0010
Epoch 9/15
211/211 ————— 339s 2s/step - accuracy: 0.5938 - loss: 0.8941 - val_accuracy: 0.3341 - val_loss: 1.6144 - learning_rate: 0.0010
Epoch 10/15
211/211 ————— 340s 2s/step - accuracy: 0.6190 - loss: 0.8516 - val_accuracy: 0.5450 - val_loss: 1.0359 - learning_rate: 0.0010
Epoch 11/15
211/211 ————— 338s 2s/step - accuracy: 0.6350 - loss: 0.8308 - val_accuracy: 0.4384 - val_loss: 1.1589 - learning_rate: 0.0010





7) Evaluate on Test Set

```
In [31]: test_loss, test_acc = model.evaluate(X_test_arr, y_test_arr, verbose=0)
print(f"Test Accuracy: {test_acc:.4f}, Test Loss: {test_loss:.4f}")

probs = model.predict(X_test_arr, verbose=0)
y_pred = np.argmax(probs, axis=1)
y_true = y_test_arr

print("\nClassification Report:")
print(classification_report(y_true, y_pred, target_names=class_names, digits=4))

cm = confusion_matrix(y_true, y_pred)
print("\nConfusion Matrix shape:", cm.shape)

def plot_confusion_matrix(cm, classes):
    plt.figure(figsize=(6,6))
    plt.imshow(cm, interpolation='nearest')
    plt.title("Confusion Matrix")
    plt.colorbar()
    ticks = np.arange(len(classes))
    plt.xticks(ticks, classes, rotation=45, ha="right")
    plt.yticks(ticks, classes)

    cm_norm = cm.astype("float") / cm.sum(axis=1)[:, np.newaxis]
    thresh = cm_norm.max() / 2.

    for i in range(cm.shape[0]):
        for j in range(cm.shape[1]):
            plt.text(j, i, format(cm[i, j], "d"),
                    horizontalalignment="center",
                    color="white" if cm_norm[i, j] > thresh else "black")

    plt.ylabel("True label")
    plt.xlabel("Predicted label")
    plt.tight_layout()
```

```
plt.show()
```

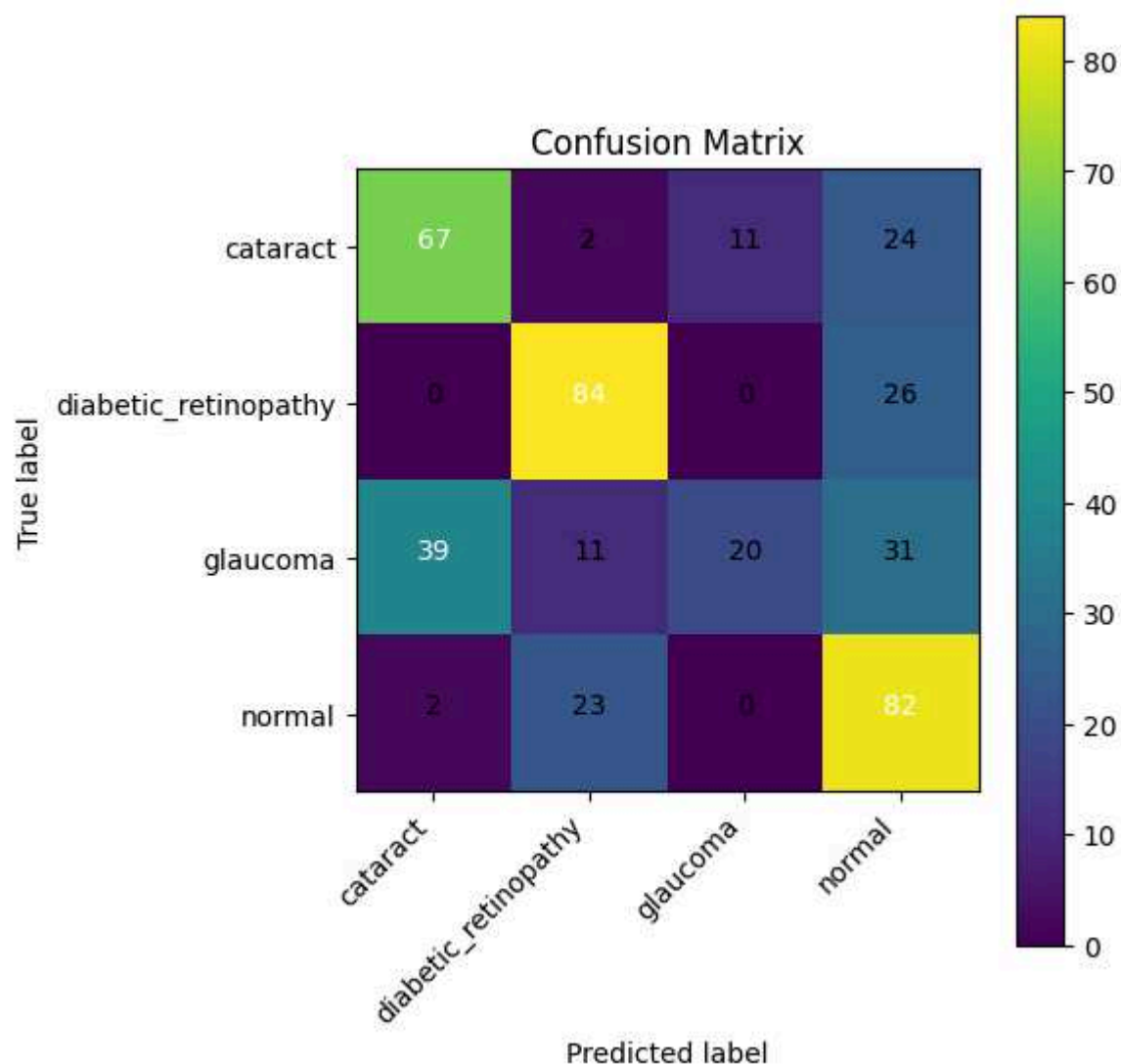
```
plot_confusion_matrix(cm, class_names)
```

Test Accuracy: 0.5995, Test Loss: 0.9868

Classification Report:

	precision	recall	f1-score	support
cataract	0.6204	0.6442	0.6321	104
diabetic_retinopathy	0.7000	0.7636	0.7304	110
glaucoma	0.6452	0.1980	0.3030	101
normal	0.5031	0.7664	0.6074	107
accuracy			0.5995	422
macro avg	0.6171	0.5931	0.5682	422
weighted avg	0.6173	0.5995	0.5727	422

Confusion Matrix shape: (4, 4)



8) Save the Model and Show Sample Predictions

```
In [32]: model.save("eye_disease_cnn_final.keras")
print("Saved model as eye_disease_cnn_final.keras")

def show_predictions(X, y, n=9):
    plt.figure(figsize=(7,7))
    side = int(np.ceil(np.sqrt(n)))

    idx = np.random.choice(len(X), size=n, replace=False)
    imgs = X[idx]
```

```
labels = y[idx]
```

```
probs = model.predict(imgs, verbose=0)  
preds = np.argmax(probs, axis=1)
```

```
for i in range(n):  
    plt.subplot(side, side, i+1)  
    plt.imshow(imgs[i])  
    true_label = class_names[labels[i]]  
    pred_label = class_names[preds[i]]  
    plt.title(f"T: {true_label}\nP: {pred_label}", fontsize=8)  
    plt.axis("off")
```

```
plt.tight_layout()  
plt.show()
```

```
show_predictions(X_test_arr, y_test_arr, n=9)
```

Saved model as eye_disease_cnn_final.keras

