DS_655_Assignment_2_Sushika

October 29, 2024

[44]:
```
!pip install nbconvert
```

```
Requirement already satisfied: nbconvert in /usr/local/lib/python3.10/dist-
packages (6.5.4)
Requirement already satisfied: lxml in /usr/local/lib/python3.10/dist-packages
(from nbconvert) (4.9.4)
Requirement already satisfied: beautifulsoup4 in /usr/local/lib/python3.10/dist-
packages (from nbconvert) (4.12.3)
Requirement already satisfied: bleach in /usr/local/lib/python3.10/dist-packages
(from nbconvert) (6.1.0)
Requirement already satisfied: defusedxml in /usr/local/lib/python3.10/dist-
packages (from nbconvert) (0.7.1)
Requirement already satisfied: entrypoints>=0.2.2 in
/usr/local/lib/python3.10/dist-packages (from nbconvert) (0.4)
Requirement already satisfied: jinja2>=3.0 in /usr/local/lib/python3.10/dist-
packages (from nbconvert) (3.1.4)
Requirement already satisfied: jupyter-core>=4.7 in
/usr/local/lib/python3.10/dist-packages (from nbconvert) (5.7.2)
Requirement already satisfied: jupyterlab-pygments in
/usr/local/lib/python3.10/dist-packages (from nbconvert) (0.3.0)
Requirement already satisfied: MarkupSafe>=2.0 in
/usr/local/lib/python3.10/dist-packages (from nbconvert) (3.0.2)
Requirement already satisfied: mistune<2,>=0.8.1 in
/usr/local/lib/python3.10/dist-packages (from nbconvert) (0.8.4)
Requirement already satisfied: nbclient>=0.5.0 in
/usr/local/lib/python3.10/dist-packages (from nbconvert) (0.10.0)
Requirement already satisfied: nbformat>=5.1 in /usr/local/lib/python3.10/dist-
packages (from nbconvert) (5.10.4)
Requirement already satisfied: packaging in /usr/local/lib/python3.10/dist-
packages (from nbconvert) (24.1)
Requirement already satisfied: pandocfilters>=1.4.1 in
/usr/local/lib/python3.10/dist-packages (from nbconvert) (1.5.1)
Requirement already satisfied: pygments>=2.4.1 in
/usr/local/lib/python3.10/dist-packages (from nbconvert) (2.18.0)
Requirement already satisfied: tinycss2 in /usr/local/lib/python3.10/dist-
packages (from nbconvert) (1.4.0)
Requirement already satisfied: traitlets>=5.0 in /usr/local/lib/python3.10/dist-
packages (from nbconvert) (5.7.1)
```

```
Requirement already satisfied: platformdirs>=2.5 in
/usr/local/lib/python3.10/dist-packages (from jupyter-core>=4.7->nbconvert)
(4.3.6)
Requirement already satisfied: jupyter-client>=6.1.12 in
/usr/local/lib/python3.10/dist-packages (from nbclient>=0.5.0->nbconvert)
(6.1.12)
Requirement already satisfied: fastjsonschema>=2.15 in
/usr/local/lib/python3.10/dist-packages (from nbformat>=5.1->nbconvert) (2.20.0)
Requirement already satisfied: jsonschema>=2.6 in
/usr/local/lib/python3.10/dist-packages (from nbformat>=5.1->nbconvert) (4.23.0)
Requirement already satisfied: soupsieve>1.2 in /usr/local/lib/python3.10/dist-
packages (from beautifulsoup4->nbconvert) (2.6)
Requirement already satisfied: six>=1.9.0 in /usr/local/lib/python3.10/dist-
packages (from bleach->nbconvert) (1.16.0)
Requirement already satisfied: webencodings in /usr/local/lib/python3.10/dist-
packages (from bleach->nbconvert) (0.5.1)
Requirement already satisfied: attrs>=22.2.0 in /usr/local/lib/python3.10/dist-
packages (from jsonschema>=2.6->nbformat>=5.1->nbconvert) (24.2.0)
Requirement already satisfied: jsonschema-specifications>=2023.03.6 in
/usr/local/lib/python3.10/dist-packages (from
jsonschema>=2.6->nbformat>=5.1->nbconvert) (2024.10.1)
Requirement already satisfied: referencing>=0.28.4 in
/usr/local/lib/python3.10/dist-packages (from
jsonschema>=2.6->nbformat>=5.1->nbconvert) (0.35.1)
Requirement already satisfied: rpds-py>=0.7.1 in /usr/local/lib/python3.10/dist-
packages (from jsonschema>=2.6->nbformat>=5.1->nbconvert) (0.20.0)
Requirement already satisfied: pyzmq>=13 in /usr/local/lib/python3.10/dist-
packages (from jupyter-client>=6.1.12->nbclient>=0.5.0->nbconvert) (24.0.1)
Requirement already satisfied: python-dateutil>=2.1 in
/usr/local/lib/python3.10/dist-packages (from jupyter-
client>=6.1.12->nbclient>=0.5.0->nbconvert) (2.8.2)
Requirement already satisfied: tornado>=4.1 in /usr/local/lib/python3.10/dist-
packages (from jupyter-client>=6.1.12->nbclient>=0.5.0->nbconvert) (6.3.3)
```

[45]:
```
!apt-get install texlive texlive-xetex texlive-latex-extra pandoc
```

```
Reading package lists… Done
Building dependency tree… Done
Reading state information… Done
pandoc is already the newest version (2.9.2.1-3ubuntu2).
texlive is already the newest version (2021.20220204-1).
texlive-latex-extra is already the newest version (2021.20220204-1).
texlive-xetex is already the newest version (2021.20220204-1).
0 upgraded, 0 newly installed, 0 to remove and 49 not upgraded.
```

[2]:
```
#drive mount
from google.colab import drive
```

```
drive.mount('/content/drive')
```

```
Mounted at /content/drive
```

[64]:
```
!ls /content/drive/MyDrive/655_deep_learning/
```

```
'Artificial Neural Networks _Regression_No_Activation_Notebook_1.ipynb'
'Artificial Neural Networks _Regression_Notebook_Activation_2.ipynb'
 Assignmenet_2_f1_scores.csv
 CIFAR_10_CNN_Sequential_Model_Notebook_2.ipynb
 Deep_Learning_Classifier.ipynb
 DS-655_Assignment_1_Sushika.ipynb
 DS-655_Assignment_1_Sushika.pdf
 DS_655_Assignment_2_Sushika.ipynb
 Hyperparameter_Tuning_with_Keras_Tuner.ipynb
 images.npy
 Labels.csv
 MNIST_CNN_Sequential_Model_Notebook_1.ipynb
 model_1_predictions_final.csv
 model_2_predictions_final.csv
 Notebook_1_Intro_to_Pixel_Theory_PIL.ipynb
 Notebook_2_Intro_to_Pixel_Theory_OpenCV.ipynb.ipynb
 Notebook_3_Edge_Detection_and_Kernels.ipynb
 picture_notebook_1.webp
 Regularization_Transfer_Learning_Keras_Tuner.ipynb
 test.csv
 train.csv
```

[66]:
```
!jupyter nbconvert --to pdf "/content/drive/655_deep_learning/
↪DS_655_Assignment_2_Sushika.ipynb"
```

```
[NbConvertApp] WARNING | pattern
'/content/drive/655_deep_learning/DS_655_Assignment_2_Sushika.ipynb' matched no
files
This application is used to convert notebook files (*.ipynb)
        to various other formats.

        WARNING: THE COMMANDLINE INTERFACE MAY CHANGE IN FUTURE RELEASES.

Options
=======
The options below are convenience aliases to configurable class-options,
as listed in the "Equivalent to" description-line of the aliases.
To see all configurable class-options for some <cmd>, use:
    <cmd> --help-all

--debug
    set log level to logging.DEBUG (maximize logging output)
```

```
    Equivalent to: [--Application.log_level=10]
--show-config
    Show the application's configuration (human-readable format)
    Equivalent to: [--Application.show_config=True]
--show-config-json
    Show the application's configuration (json format)
    Equivalent to: [--Application.show_config_json=True]
--generate-config
    generate default config file
    Equivalent to: [--JupyterApp.generate_config=True]
-y
    Answer yes to any questions instead of prompting.
    Equivalent to: [--JupyterApp.answer_yes=True]
--execute
    Execute the notebook prior to export.
    Equivalent to: [--ExecutePreprocessor.enabled=True]
--allow-errors
    Continue notebook execution even if one of the cells throws an error and
include the error message in the cell output (the default behaviour is to abort
conversion). This flag is only relevant if '--execute' was specified, too.
    Equivalent to: [--ExecutePreprocessor.allow_errors=True]
--stdin
    read a single notebook file from stdin. Write the resulting notebook with
default basename 'notebook.*'
    Equivalent to: [--NbConvertApp.from_stdin=True]
--stdout
    Write notebook output to stdout instead of files.
    Equivalent to: [--NbConvertApp.writer_class=StdoutWriter]
--inplace
    Run nbconvert in place, overwriting the existing notebook (only
            relevant when converting to notebook format)
    Equivalent to: [--NbConvertApp.use_output_suffix=False
--NbConvertApp.export_format=notebook --FilesWriter.build_directory=]
--clear-output
    Clear output of current file and save in place,
            overwriting the existing notebook.
    Equivalent to: [--NbConvertApp.use_output_suffix=False
--NbConvertApp.export_format=notebook --FilesWriter.build_directory=
--ClearOutputPreprocessor.enabled=True]
--no-prompt
    Exclude input and output prompts from converted document.
    Equivalent to: [--TemplateExporter.exclude_input_prompt=True
--TemplateExporter.exclude_output_prompt=True]
--no-input
    Exclude input cells and output prompts from converted document.
            This mode is ideal for generating code-free reports.
    Equivalent to: [--TemplateExporter.exclude_output_prompt=True
--TemplateExporter.exclude_input=True
```

```
--TemplateExporter.exclude_input_prompt=True]
--allow-chromium-download
    Whether to allow downloading chromium if no suitable version is found on the
system.
    Equivalent to: [--WebPDFExporter.allow_chromium_download=True]
--disable-chromium-sandbox
    Disable chromium security sandbox when converting to PDF..
    Equivalent to: [--WebPDFExporter.disable_sandbox=True]
--show-input
    Shows code input. This flag is only useful for dejavu users.
    Equivalent to: [--TemplateExporter.exclude_input=False]
--embed-images
    Embed the images as base64 dataurls in the output. This flag is only useful
for the HTML/WebPDF/Slides exports.
    Equivalent to: [--HTMLExporter.embed_images=True]
--sanitize-html
    Whether the HTML in Markdown cells and cell outputs should be sanitized..
    Equivalent to: [--HTMLExporter.sanitize_html=True]
--log-level=<Enum>
    Set the log level by value or name.
    Choices: any of [0, 10, 20, 30, 40, 50, 'DEBUG', 'INFO', 'WARN', 'ERROR',
'CRITICAL']
    Default: 30
    Equivalent to: [--Application.log_level]
--config=<Unicode>
    Full path of a config file.
    Default: ''
    Equivalent to: [--JupyterApp.config_file]
--to=<Unicode>
    The export format to be used, either one of the built-in formats
            ['asciidoc', 'custom', 'html', 'latex', 'markdown', 'notebook',
'pdf', 'python', 'rst', 'script', 'slides', 'webpdf']
            or a dotted object name that represents the import path for an
            ``Exporter`` class
    Default: ''
    Equivalent to: [--NbConvertApp.export_format]
--template=<Unicode>
    Name of the template to use
    Default: ''
    Equivalent to: [--TemplateExporter.template_name]
--template-file=<Unicode>
    Name of the template file to use
    Default: None
    Equivalent to: [--TemplateExporter.template_file]
--theme=<Unicode>
    Template specific theme(e.g. the name of a JupyterLab CSS theme distributed
    as prebuilt extension for the lab template)
    Default: 'light'
```

```
    Equivalent to: [--HTMLExporter.theme]
--sanitize_html=<Bool>
    Whether the HTML in Markdown cells and cell outputs should be sanitized.This
    should be set to True by nbviewer or similar tools.
    Default: False
    Equivalent to: [--HTMLExporter.sanitize_html]
--writer=<DottedObjectName>
    Writer class used to write the
                                        results of the conversion
    Default: 'FilesWriter'
    Equivalent to: [--NbConvertApp.writer_class]
--post=<DottedOrNone>
    PostProcessor class used to write the
                                        results of the conversion
    Default: ''
    Equivalent to: [--NbConvertApp.postprocessor_class]
--output=<Unicode>
    overwrite base name use for output files.
                can only be used when converting one notebook at a time.
    Default: ''
    Equivalent to: [--NbConvertApp.output_base]
--output-dir=<Unicode>
    Directory to write output(s) to. Defaults
                                    to output to the directory of each notebook.
To recover
                                    previous default behaviour (outputting to the
current
                                    working directory) use . as the flag value.
    Default: ''
    Equivalent to: [--FilesWriter.build_directory]
--reveal-prefix=<Unicode>
    The URL prefix for reveal.js (version 3.x).
            This defaults to the reveal CDN, but can be any url pointing to a
copy
            of reveal.js.
            For speaker notes to work, this must be a relative path to a local
            copy of reveal.js: e.g., "reveal.js".
            If a relative path is given, it must be a subdirectory of the
            current directory (from which the server is run).
            See the usage documentation
            (https://nbconvert.readthedocs.io/en/latest/usage.html#reveal-js-
html-slideshow)
            for more details.
    Default: ''
    Equivalent to: [--SlidesExporter.reveal_url_prefix]
--nbformat=<Enum>
    The nbformat version to write.
            Use this to downgrade notebooks.
```

```
    Choices: any of [1, 2, 3, 4]
    Default: 4
    Equivalent to: [--NotebookExporter.nbformat_version]

Examples
--------

    The simplest way to use nbconvert is

            > jupyter nbconvert mynotebook.ipynb --to html

            Options include ['asciidoc', 'custom', 'html', 'latex', 'markdown',
'notebook', 'pdf', 'python', 'rst', 'script', 'slides', 'webpdf'].

            > jupyter nbconvert --to latex mynotebook.ipynb

            Both HTML and LaTeX support multiple output templates. LaTeX
includes
            'base', 'article' and 'report'.  HTML includes 'basic', 'lab' and
            'classic'. You can specify the flavor of the format used.

            > jupyter nbconvert --to html --template lab mynotebook.ipynb

            You can also pipe the output to stdout, rather than a file

            > jupyter nbconvert mynotebook.ipynb --stdout

            PDF is generated via latex

            > jupyter nbconvert mynotebook.ipynb --to pdf

            You can get (and serve) a Reveal.js-powered slideshow

            > jupyter nbconvert myslides.ipynb --to slides --post serve

            Multiple notebooks can be given at the command line in a couple of
            different ways:

            > jupyter nbconvert notebook*.ipynb
            > jupyter nbconvert notebook1.ipynb notebook2.ipynb

            or you can specify the notebooks list in a config file, containing::

                c.NbConvertApp.notebooks = ["my_notebook.ipynb"]

            > jupyter nbconvert --config mycfg.py

To see all available configurables, use `--help-all`.
```

[49]:
```
!jupyter nbconvert --to pdf //DS_655_Assignment_2_Sushika.ipynb
```

```
[NbConvertApp] WARNING | pattern
'/path_to_your_notebook/DS_655_Assignment_2_Sushika.ipynb' matched no files
This application is used to convert notebook files (*.ipynb)
        to various other formats.

        WARNING: THE COMMANDLINE INTERFACE MAY CHANGE IN FUTURE RELEASES.

Options
=======
The options below are convenience aliases to configurable class-options,
as listed in the "Equivalent to" description-line of the aliases.
To see all configurable class-options for some <cmd>, use:
    <cmd> --help-all

--debug
    set log level to logging.DEBUG (maximize logging output)
    Equivalent to: [--Application.log_level=10]
--show-config
    Show the application's configuration (human-readable format)
    Equivalent to: [--Application.show_config=True]
--show-config-json
    Show the application's configuration (json format)
    Equivalent to: [--Application.show_config_json=True]
--generate-config
    generate default config file
    Equivalent to: [--JupyterApp.generate_config=True]
-y
    Answer yes to any questions instead of prompting.
    Equivalent to: [--JupyterApp.answer_yes=True]
--execute
    Execute the notebook prior to export.
    Equivalent to: [--ExecutePreprocessor.enabled=True]
--allow-errors
    Continue notebook execution even if one of the cells throws an error and
include the error message in the cell output (the default behaviour is to abort
conversion). This flag is only relevant if '--execute' was specified, too.
    Equivalent to: [--ExecutePreprocessor.allow_errors=True]
--stdin
    read a single notebook file from stdin. Write the resulting notebook with
default basename 'notebook.*'
    Equivalent to: [--NbConvertApp.from_stdin=True]
--stdout
    Write notebook output to stdout instead of files.
    Equivalent to: [--NbConvertApp.writer_class=StdoutWriter]
```

```
--inplace
    Run nbconvert in place, overwriting the existing notebook (only
            relevant when converting to notebook format)
    Equivalent to: [--NbConvertApp.use_output_suffix=False
--NbConvertApp.export_format=notebook --FilesWriter.build_directory=]
--clear-output
    Clear output of current file and save in place,
            overwriting the existing notebook.
    Equivalent to: [--NbConvertApp.use_output_suffix=False
--NbConvertApp.export_format=notebook --FilesWriter.build_directory=
--ClearOutputPreprocessor.enabled=True]
--no-prompt
    Exclude input and output prompts from converted document.
    Equivalent to: [--TemplateExporter.exclude_input_prompt=True
--TemplateExporter.exclude_output_prompt=True]
--no-input
    Exclude input cells and output prompts from converted document.
            This mode is ideal for generating code-free reports.
    Equivalent to: [--TemplateExporter.exclude_output_prompt=True
--TemplateExporter.exclude_input=True
--TemplateExporter.exclude_input_prompt=True]
--allow-chromium-download
    Whether to allow downloading chromium if no suitable version is found on the
system.
    Equivalent to: [--WebPDFExporter.allow_chromium_download=True]
--disable-chromium-sandbox
    Disable chromium security sandbox when converting to PDF..
    Equivalent to: [--WebPDFExporter.disable_sandbox=True]
--show-input
    Shows code input. This flag is only useful for dejavu users.
    Equivalent to: [--TemplateExporter.exclude_input=False]
--embed-images
    Embed the images as base64 dataurls in the output. This flag is only useful
for the HTML/WebPDF/Slides exports.
    Equivalent to: [--HTMLExporter.embed_images=True]
--sanitize-html
    Whether the HTML in Markdown cells and cell outputs should be sanitized..
    Equivalent to: [--HTMLExporter.sanitize_html=True]
--log-level=<Enum>
    Set the log level by value or name.
    Choices: any of [0, 10, 20, 30, 40, 50, 'DEBUG', 'INFO', 'WARN', 'ERROR',
'CRITICAL']
    Default: 30
    Equivalent to: [--Application.log_level]
--config=<Unicode>
    Full path of a config file.
    Default: ''
    Equivalent to: [--JupyterApp.config_file]
```

```
--to=<Unicode>
    The export format to be used, either one of the built-in formats
            ['asciidoc', 'custom', 'html', 'latex', 'markdown', 'notebook',
'pdf', 'python', 'rst', 'script', 'slides', 'webpdf']
            or a dotted object name that represents the import path for an
            ``Exporter`` class
    Default: ''
    Equivalent to: [--NbConvertApp.export_format]
--template=<Unicode>
    Name of the template to use
    Default: ''
    Equivalent to: [--TemplateExporter.template_name]
--template-file=<Unicode>
    Name of the template file to use
    Default: None
    Equivalent to: [--TemplateExporter.template_file]
--theme=<Unicode>
    Template specific theme(e.g. the name of a JupyterLab CSS theme distributed
    as prebuilt extension for the lab template)
    Default: 'light'
    Equivalent to: [--HTMLExporter.theme]
--sanitize_html=<Bool>
    Whether the HTML in Markdown cells and cell outputs should be sanitized.This
    should be set to True by nbviewer or similar tools.
    Default: False
    Equivalent to: [--HTMLExporter.sanitize_html]
--writer=<DottedObjectName>
    Writer class used to write the
                                        results of the conversion
    Default: 'FilesWriter'
    Equivalent to: [--NbConvertApp.writer_class]
--post=<DottedOrNone>
    PostProcessor class used to write the
                                        results of the conversion
    Default: ''
    Equivalent to: [--NbConvertApp.postprocessor_class]
--output=<Unicode>
    overwrite base name use for output files.
                can only be used when converting one notebook at a time.
    Default: ''
    Equivalent to: [--NbConvertApp.output_base]
--output-dir=<Unicode>
    Directory to write output(s) to. Defaults
                                    to output to the directory of each notebook.
To recover
                                    previous default behaviour (outputting to the
current
                                    working directory) use . as the flag value.
```

```
    Default: ''
    Equivalent to: [--FilesWriter.build_directory]
--reveal-prefix=<Unicode>
    The URL prefix for reveal.js (version 3.x).
            This defaults to the reveal CDN, but can be any url pointing to a
copy
            of reveal.js.
            For speaker notes to work, this must be a relative path to a local
            copy of reveal.js: e.g., "reveal.js".
            If a relative path is given, it must be a subdirectory of the
            current directory (from which the server is run).
            See the usage documentation
            (https://nbconvert.readthedocs.io/en/latest/usage.html#reveal-js-
html-slideshow)
            for more details.
    Default: ''
    Equivalent to: [--SlidesExporter.reveal_url_prefix]
--nbformat=<Enum>
    The nbformat version to write.
            Use this to downgrade notebooks.
    Choices: any of [1, 2, 3, 4]
    Default: 4
    Equivalent to: [--NotebookExporter.nbformat_version]

Examples
--------

    The simplest way to use nbconvert is

            > jupyter nbconvert mynotebook.ipynb --to html

            Options include ['asciidoc', 'custom', 'html', 'latex', 'markdown',
'notebook', 'pdf', 'python', 'rst', 'script', 'slides', 'webpdf'].

            > jupyter nbconvert --to latex mynotebook.ipynb

            Both HTML and LaTeX support multiple output templates. LaTeX
includes
            'base', 'article' and 'report'.  HTML includes 'basic', 'lab' and
            'classic'. You can specify the flavor of the format used.

            > jupyter nbconvert --to html --template lab mynotebook.ipynb

            You can also pipe the output to stdout, rather than a file

            > jupyter nbconvert mynotebook.ipynb --stdout

            PDF is generated via latex
```

```
> jupyter nbconvert mynotebook.ipynb --to pdf

You can get (and serve) a Reveal.js-powered slideshow

> jupyter nbconvert myslides.ipynb --to slides --post serve

Multiple notebooks can be given at the command line in a couple of
different ways:

> jupyter nbconvert notebook*.ipynb
> jupyter nbconvert notebook1.ipynb notebook2.ipynb

or you can specify the notebooks list in a config file, containing::

    c.NbConvertApp.notebooks = ["my_notebook.ipynb"]

> jupyter nbconvert --config mycfg.py

To see all available configurables, use `--help-all`.
```

[4]:
```
import keras
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns

import tensorflow as tf

# Keras Sequential Model
from tensorflow.keras.models import Sequential

# Importing all the different layers and optimizers
from tensorflow.keras.layers import Dense, Dropout, Flatten, Conv2D,␣
 ↪MaxPooling2D, BatchNormalization, Activation, LeakyReLU
from tensorflow.keras.optimizers import Adam
```

[5]:
```
# Ensure that you have the latest versions of the libraries installed:
!pip install --upgrade pillow matplotlib
#import warnings
#warnings.filterwarnings('ignore')

# Importing the latest versions of the libraries
from PIL import Image
import matplotlib.pyplot as plt
```

```
Requirement already satisfied: pillow in /usr/local/lib/python3.10/dist-packages
```

```
(11.0.0)
Requirement already satisfied: matplotlib in /usr/local/lib/python3.10/dist-
packages (3.9.2)
Requirement already satisfied: contourpy>=1.0.1 in
/usr/local/lib/python3.10/dist-packages (from matplotlib) (1.3.0)
Requirement already satisfied: cycler>=0.10 in /usr/local/lib/python3.10/dist-
packages (from matplotlib) (0.12.1)
Requirement already satisfied: fonttools>=4.22.0 in
/usr/local/lib/python3.10/dist-packages (from matplotlib) (4.54.1)
Requirement already satisfied: kiwisolver>=1.3.1 in
/usr/local/lib/python3.10/dist-packages (from matplotlib) (1.4.7)
Requirement already satisfied: numpy>=1.23 in /usr/local/lib/python3.10/dist-
packages (from matplotlib) (1.26.4)
Requirement already satisfied: packaging>=20.0 in
/usr/local/lib/python3.10/dist-packages (from matplotlib) (24.1)
Requirement already satisfied: pyparsing>=2.3.1 in
/usr/local/lib/python3.10/dist-packages (from matplotlib) (3.2.0)
Requirement already satisfied: python-dateutil>=2.7 in
/usr/local/lib/python3.10/dist-packages (from matplotlib) (2.8.2)
Requirement already satisfied: six>=1.5 in /usr/local/lib/python3.10/dist-
packages (from python-dateutil>=2.7->matplotlib) (1.16.0)
```

1 Step 1: Exploratory Data Analysis (EDA)

1.1 1.1 Loading the Dataset

[6]:
```python
# Load the images from .npy file
images = np.load('/content/drive/MyDrive/655_deep_learning/images.npy')

# Load the labels from .csv file
labels_df = pd.read_csv('/content/drive/MyDrive/655_deep_learning/Labels.csv')

# Display the first few rows of labels to verify successful loading
print(labels_df.head())
print(f"\n Shape of images: {images.shape}")
print(f"\n Shape of labels: {labels_df.shape}")
```

```
                     Label
0  Small-flowered Cranesbill
1  Small-flowered Cranesbill
2  Small-flowered Cranesbill
3  Small-flowered Cranesbill
4  Small-flowered Cranesbill

 Shape of images: (4750, 128, 128, 3)

 Shape of labels: (4750, 1)
```

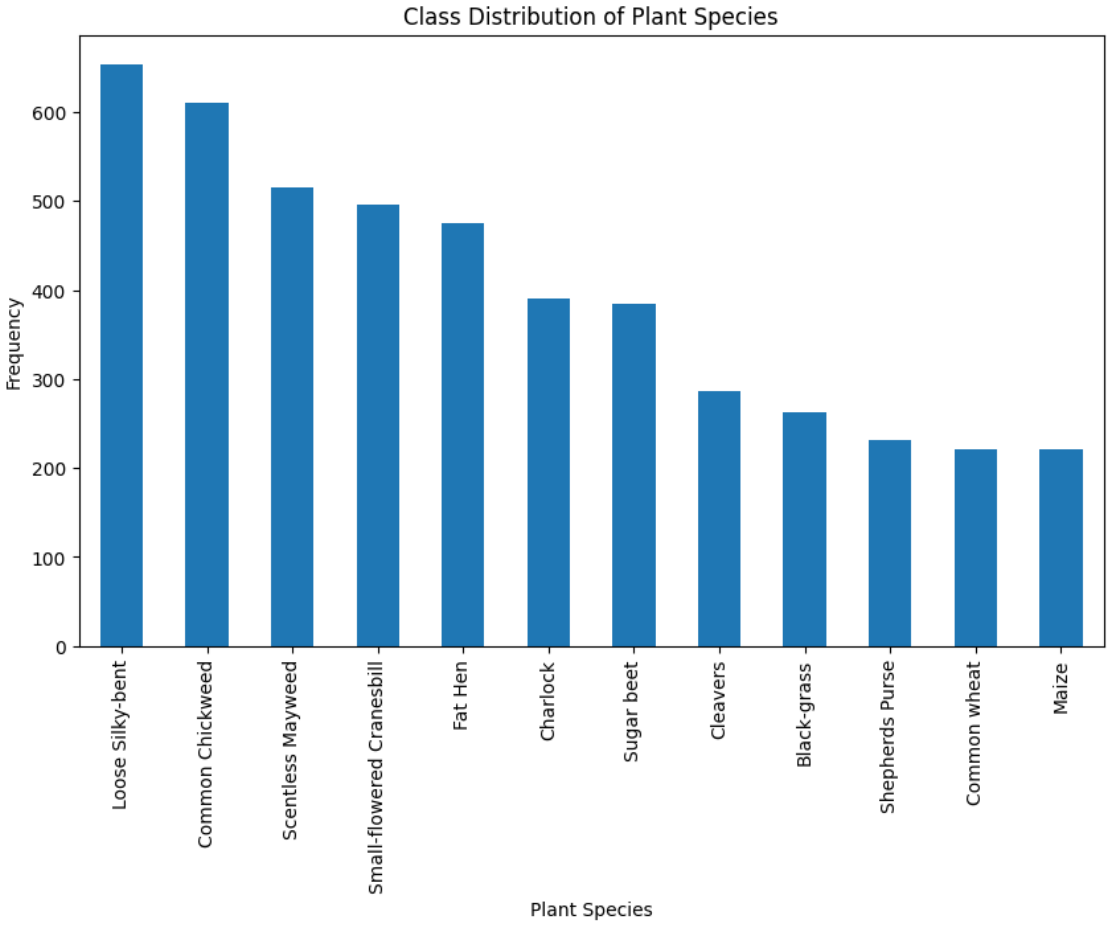
[7]:
```
print(labels_df.columns)
```

```
Index(['Label'], dtype='object')
```

1.2 1.2 Visualize Class Distribution

Reference: The approach for plotting class distributions is taken from Week 6 lecture, MNIST_CNN_Sequential_Model, where class frequency visualizations help in analyzing dataset balance.

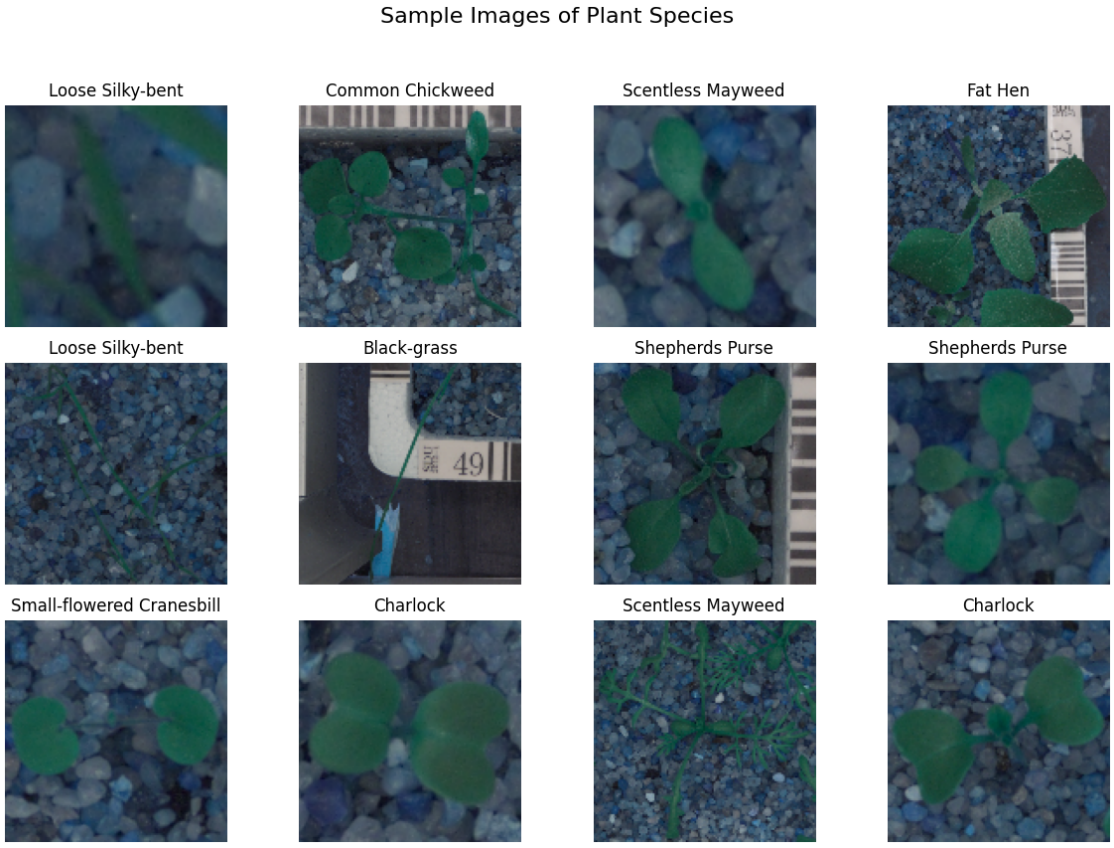
[8]:
```
import matplotlib.pyplot as plt

# Plot the class distribution
plt.figure(figsize=(10, 6))
labels_df['Label'].value_counts().plot(kind='bar')
plt.title('Class Distribution of Plant Species')
plt.xlabel('Plant Species')
plt.ylabel('Frequency')
plt.show()
```



1.3 1.3 Plot Sample Images in a 3x4 Grid

Reference: Displaying a grid of sample images with corresponding labels follows a similar visualization structure as in Week 6 lecture, CIFAR_10_CNN_Sequential_Model, which provides examples of displaying images in grids.

[9]:
```
import random

# Set up a 3x4 grid for sample images
fig, axes = plt.subplots(3, 4, figsize=(12, 9))
fig.suptitle('Sample Images of Plant Species', fontsize=16)

# Randomly select 12 images
sample_indices = random.sample(range(len(images)), 12)
for idx, ax in zip(sample_indices, axes.flat):
    ax.imshow(images[idx])
    ax.set_title(labels_df['Label'].iloc[idx])
    ax.axis('off')

plt.tight_layout(rect=[0, 0.03, 1, 0.95])
plt.show()
```



2 Step 2: Data Preprocessing

2.1 2.1 Resize Images to 64x64

Reference: The resizing technique takes cues from Week 6 CIFAR_10_CNN_Sequential_Model, where image dimensions are adjusted for computational efficiency.

[10]:
```
import cv2
# Resize images to 64x64
images_resized = np.array([cv2.resize(img, (64, 64)) for img in images])
print(f"Resized images shape: {images_resized.shape}")
```

```
Resized images shape: (4750, 64, 64, 3)
```

2.2 2.2 Encode Target Variables

Reference: The encoding approach is adapted from Week 6 lecture, MNIST_CNN_Sequential_Model, which encodes labels to prepare them for classification.

[11]:
```
from sklearn.preprocessing import LabelEncoder

# Encode plant species labels using LabelEncoder
label_encoder = LabelEncoder()
labels_encoded = label_encoder.fit_transform(labels_df['Label'])

# Display encoded labels sample
print(f"Label Encoded Sample: {labels_encoded[:5]}")
print(f"Classes: {label_encoder.classes_}")
```

```
Label Encoded Sample: [10 10 10 10 10]
Classes: ['Black-grass' 'Charlock' 'Cleavers' 'Common Chickweed' 'Common wheat'
 'Fat Hen' 'Loose Silky-bent' 'Maize' 'Scentless Mayweed'
 'Shepherds Purse' 'Small-flowered Cranesbill' 'Sugar beet']
```

2.3 2.3 Normalize the Images

Reference: The normalization technique aligns with the data preprocessing steps in Week 6 lecture , CIFAR_10_CNN_Sequential_Model, where pixel values are scaled to improve training stability.

[12]:
```
# Normalize the images by scaling pixel values between 0 and 1
images_normalized = images_resized / 255.0
print(f"Normalized images range: Min={images_normalized.min()},␣
  ↪Max={images_normalized.max()}")
```

```
Normalized images range: Min=0.0, Max=1.0
```

3 Model 1: Basic CNN Model

3.1 3.1 Build a Basic CNN Model

Reference: The architecture and general model structure are inspired by CIFAR_10_CNN_Sequential_Model, which uses a simple CNN model suitable for image classification.

[13]:
```
import tensorflow as tf
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Conv2D, MaxPooling2D, Flatten, Dense,␣
↪Dropout
from tensorflow.keras.callbacks import EarlyStopping

# Define the CNN model architecture
model = Sequential([
    Conv2D(32, (3, 3), activation='relu', input_shape=(64, 64, 3)),
    MaxPooling2D((2, 2)),
    Conv2D(64, (3, 3), activation='relu'),
    MaxPooling2D((2, 2)),
    Conv2D(128, (3, 3), activation='relu'),
    MaxPooling2D((2, 2)),
    Flatten(),
    Dense(128, activation='relu'),
    Dropout(0.5),
    Dense(12, activation='softmax')  # 12 output units for 12 classes
])

# Compile the model
model.compile(optimizer='adam', loss='sparse_categorical_crossentropy',␣
↪metrics=['accuracy'])

# Display model summary
model.summary()
```

```
/usr/local/lib/python3.10/dist-
packages/keras/src/layers/convolutional/base_conv.py:107: UserWarning: Do not
pass an `input_shape`/`input_dim` argument to a layer. When using Sequential
models, prefer using an `Input(shape)` object as the first layer in the model
instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
Model: "sequential"
```

Layer (type)	Output Shape	Param #

```
conv2d (Conv2D)                      (None, 62, 62, 32)                ␣
↪896

max_pooling2d (MaxPooling2D)         (None, 31, 31, 32)                ␣
↪  0

conv2d_1 (Conv2D)                    (None, 29, 29, 64)                ␣
↪18,496

max_pooling2d_1 (MaxPooling2D)       (None, 14, 14, 64)                ␣
↪  0

conv2d_2 (Conv2D)                    (None, 12, 12, 128)               ␣
↪73,856

max_pooling2d_2 (MaxPooling2D)       (None, 6, 6, 128)                 ␣
↪  0

flatten (Flatten)                    (None, 4608)                      ␣
↪  0

dense (Dense)                        (None, 128)                       ␣
↪589,952

dropout (Dropout)                    (None, 128)                       ␣
↪  0

dense_1 (Dense)                      (None, 12)                        ␣
↪1,548


Total params: 684,748 (2.61 MB)

Trainable params: 684,748 (2.61 MB)

Non-trainable params: 0 (0.00 B)
```

3.2 3.2 Train the Model with Early Stopping

Reference: The training process with accuracy and loss tracking is based on CIFAR_10_CNN_Sequential_Model. Early stopping is included to prevent overfitting.

[14]:
```
# Split the data
from sklearn.model_selection import train_test_split
```

```
# Split data into training and validation sets
X_train, X_val, y_train, y_val = train_test_split(images_normalized,␣
 ↪labels_encoded, test_size=0.2, random_state=42)

# Define early stopping callback
early_stopping = EarlyStopping(monitor='val_loss', patience=5,␣
 ↪restore_best_weights=True)

# Train the model
history = model.fit(
    X_train, y_train,
    validation_data=(X_val, y_val),
    epochs=20,
    batch_size=32,
    callbacks=[early_stopping]
)
```

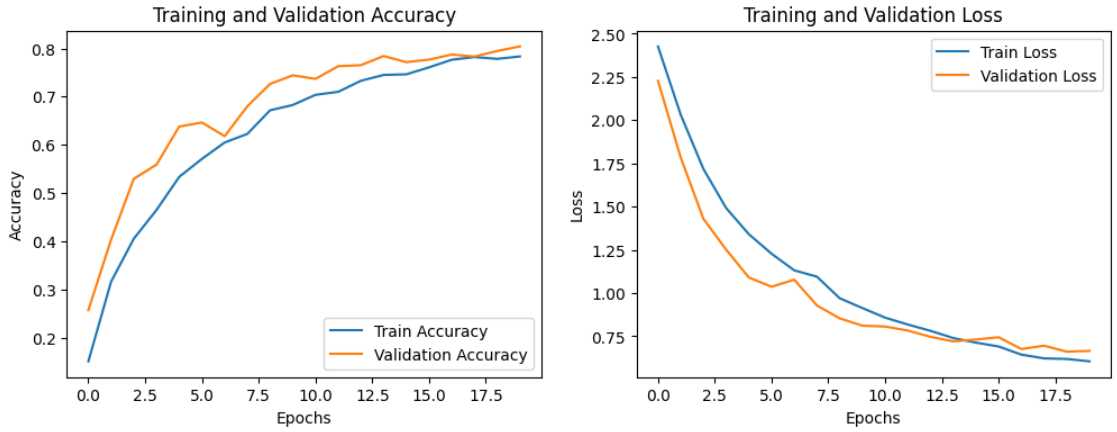
```
Epoch 1/20
119/119             14s 65ms/step -
accuracy: 0.1361 - loss: 2.4539 - val_accuracy: 0.2568 - val_loss: 2.2272
Epoch 2/20
119/119             9s 9ms/step -
accuracy: 0.2863 - loss: 2.1343 - val_accuracy: 0.4032 - val_loss: 1.7840
Epoch 3/20
119/119             1s 7ms/step -
accuracy: 0.3846 - loss: 1.7630 - val_accuracy: 0.5295 - val_loss: 1.4296
Epoch 4/20
119/119             1s 6ms/step -
accuracy: 0.4573 - loss: 1.5429 - val_accuracy: 0.5589 - val_loss: 1.2514
Epoch 5/20
119/119             1s 6ms/step -
accuracy: 0.5225 - loss: 1.3705 - val_accuracy: 0.6379 - val_loss: 1.0902
Epoch 6/20
119/119             1s 6ms/step -
accuracy: 0.5652 - loss: 1.2335 - val_accuracy: 0.6463 - val_loss: 1.0366
Epoch 7/20
119/119             1s 6ms/step -
accuracy: 0.5891 - loss: 1.1472 - val_accuracy: 0.6179 - val_loss: 1.0772
Epoch 8/20
119/119             1s 6ms/step -
accuracy: 0.5971 - loss: 1.1551 - val_accuracy: 0.6800 - val_loss: 0.9284
Epoch 9/20
119/119             1s 6ms/step -
accuracy: 0.6726 - loss: 0.9710 - val_accuracy: 0.7263 - val_loss: 0.8535
Epoch 10/20
119/119             1s 7ms/step -
accuracy: 0.6801 - loss: 0.9138 - val_accuracy: 0.7442 - val_loss: 0.8115
```

```
Epoch 11/20
119/119             1s 7ms/step -
accuracy: 0.7044 - loss: 0.8458 - val_accuracy: 0.7368 - val_loss: 0.8064
Epoch 12/20
119/119             1s 6ms/step -
accuracy: 0.7080 - loss: 0.8163 - val_accuracy: 0.7632 - val_loss: 0.7836
Epoch 13/20
119/119             1s 8ms/step -
accuracy: 0.7387 - loss: 0.7573 - val_accuracy: 0.7653 - val_loss: 0.7468
Epoch 14/20
119/119             1s 8ms/step -
accuracy: 0.7480 - loss: 0.7496 - val_accuracy: 0.7842 - val_loss: 0.7208
Epoch 15/20
119/119             1s 8ms/step -
accuracy: 0.7505 - loss: 0.7065 - val_accuracy: 0.7716 - val_loss: 0.7316
Epoch 16/20
119/119             1s 8ms/step -
accuracy: 0.7708 - loss: 0.6547 - val_accuracy: 0.7768 - val_loss: 0.7444
Epoch 17/20
119/119             1s 6ms/step -
accuracy: 0.7903 - loss: 0.6189 - val_accuracy: 0.7874 - val_loss: 0.6765
Epoch 18/20
119/119             1s 7ms/step -
accuracy: 0.7782 - loss: 0.6225 - val_accuracy: 0.7832 - val_loss: 0.6957
Epoch 19/20
119/119             1s 8ms/step -
accuracy: 0.7790 - loss: 0.6097 - val_accuracy: 0.7947 - val_loss: 0.6611
Epoch 20/20
119/119             1s 8ms/step -
accuracy: 0.7717 - loss: 0.6385 - val_accuracy: 0.8042 - val_loss: 0.6655
```

3.3 3.3 Plot Accuracy and Loss Curves

[15]:
```python
import matplotlib.pyplot as plt

# Plot training & validation accuracy and loss
plt.figure(figsize=(12, 4))

# Accuracy plot
plt.subplot(1, 2, 1)
plt.plot(history.history['accuracy'], label='Train Accuracy')
plt.plot(history.history['val_accuracy'], label='Validation Accuracy')
plt.title('Training and Validation Accuracy')
plt.xlabel('Epochs')
plt.ylabel('Accuracy')
plt.legend()
```

```
# Loss plot
plt.subplot(1, 2, 2)
plt.plot(history.history['loss'], label='Train Loss')
plt.plot(history.history['val_loss'], label='Validation Loss')
plt.title('Training and Validation Loss')
plt.xlabel('Epochs')
plt.ylabel('Loss')
plt.legend()

plt.show()
```

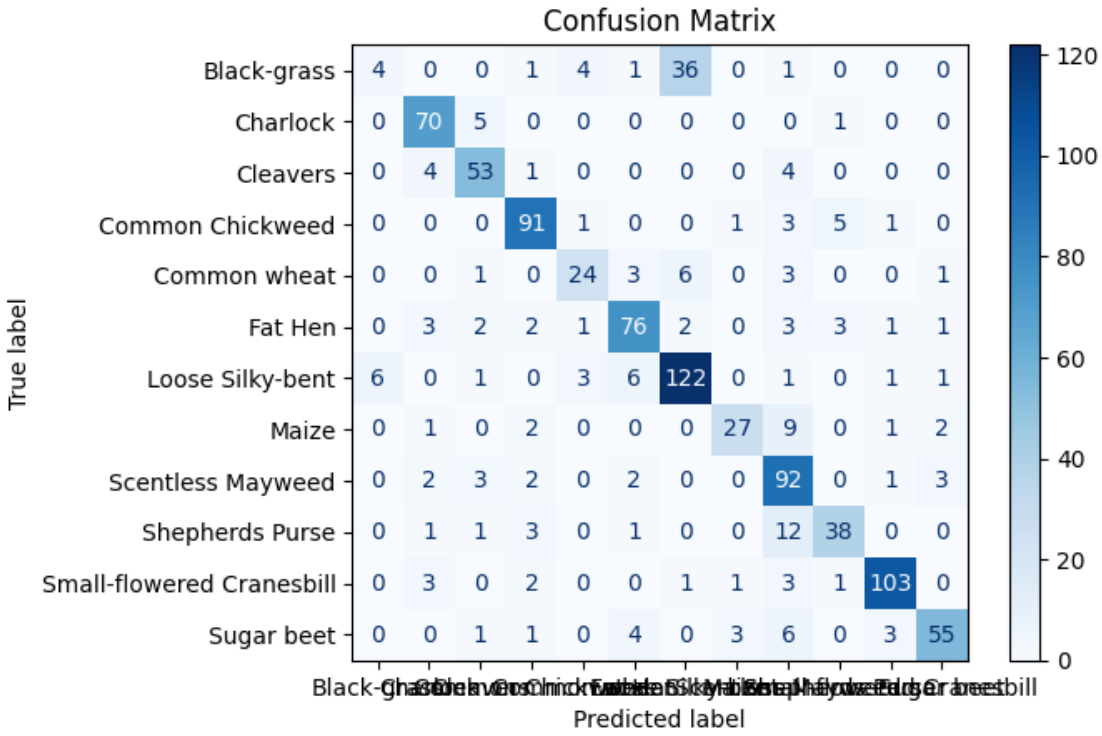


3.4 3.4 Evaluate Model Performance with a Confusion Matrix

Reference: The confusion matrix and classification report steps are adapted from CIFAR_10_CNN_Sequential_Model, where model evaluation across classes is demonstrated.

[16]:
```
from sklearn.metrics import confusion_matrix, ConfusionMatrixDisplay,␣
 ↪classification_report

# Predict on the validation set
y_pred = np.argmax(model.predict(X_val), axis=1)

# Plot confusion matrix
cm = confusion_matrix(y_val, y_pred)
disp = ConfusionMatrixDisplay(confusion_matrix=cm, display_labels=label_encoder.
 ↪classes_)
disp.plot(cmap=plt.cm.Blues)
plt.title('Confusion Matrix')
plt.show()

# Print classification report
print(classification_report(y_val, y_pred, target_names=label_encoder.classes_))
```

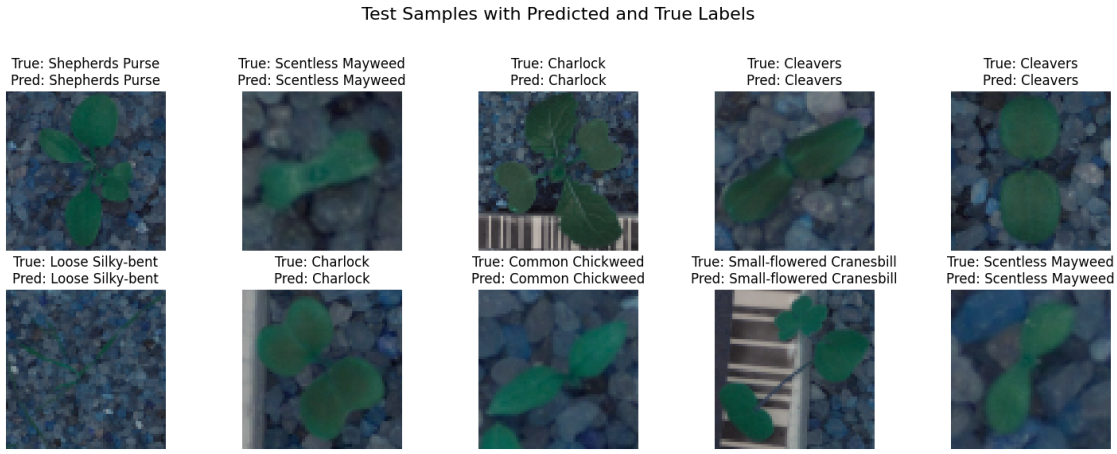
```
30/30                1s 11ms/step
```



	precision	recall	f1-score	support
Black-grass	0.40	0.09	0.14	47
Charlock	0.83	0.92	0.88	76
Cleavers	0.79	0.85	0.82	62
Common Chickweed	0.87	0.89	0.88	102
Common wheat	0.73	0.63	0.68	38
Fat Hen	0.82	0.81	0.81	94
Loose Silky-bent	0.73	0.87	0.79	141
Maize	0.84	0.64	0.73	42
Scentless Mayweed	0.67	0.88	0.76	105
Shepherds Purse	0.79	0.68	0.73	56
Small-flowered Cranesbill	0.93	0.90	0.92	114
Sugar beet	0.87	0.75	0.81	73
accuracy			0.79	950
macro avg	0.77	0.74	0.75	950
weighted avg	0.79	0.79	0.78	950

3.5 3.5 Visualize Test Samples with Predictions

[17]:
```
# Visualize a few test samples with their predicted and true labels
import random

fig, axes = plt.subplots(2, 5, figsize=(15, 6))
fig.suptitle('Test Samples with Predicted and True Labels', fontsize=16)

sample_indices = random.sample(range(len(X_val)), 10)
for idx, ax in zip(sample_indices, axes.flat):
    ax.imshow(X_val[idx])
    ax.set_title(f"True: {label_encoder.
 ↪inverse_transform([y_val[idx]])[0]}\nPred: {label_encoder.
 ↪inverse_transform([y_pred[idx]])[0]}")
    ax.axis('off')

plt.tight_layout(rect=[0, 0.03, 1, 0.95])
plt.show()
```



4 Step 4: Model 2 - Enhanced CNN with Data Augmentation and Regularization

4.1 4.1 Data Augmentation

Reference: The data augmentation process is based on techniques from CIFAR_10_CNN_Sequential_Model, where various augmentations are applied to improve model robustness.

[22]:
```
from tensorflow.keras.preprocessing.image import ImageDataGenerator

# Define data augmentation techniques
```

```
datagen = ImageDataGenerator(
    rotation_range=10,      # Random rotation between 0 and 20 degrees
    width_shift_range=0.1, # Random horizontal shift
    height_shift_range=0.1, # Random vertical shift
    zoom_range=0.2,         # Random zoom
    horizontal_flip=True    # Random horizontal flip
)

# Fit the data generator on training images
datagen.fit(X_train)
```

4.2 4.2 Build the Enhanced CNN Model with Batch Normalization and Spatial Dropout

Reference: The model architecture with batch normalization and spatial dropout is adapted from MNIST_CNN_Sequential_Model, which includes techniques for regularization and training stability.

[23]:
```
from tensorflow.keras.layers import BatchNormalization, SpatialDropout2D

# Define an enhanced CNN model architecture
enhanced_model = Sequential([
    Conv2D(32, (3, 3), activation='relu', input_shape=(64, 64, 3)),
    BatchNormalization(),
    MaxPooling2D((2, 2)),
    SpatialDropout2D(0.3),  # Spatial Dropout for regularization

    Conv2D(64, (3, 3), activation='relu'),
    BatchNormalization(),
    MaxPooling2D((2, 2)),
    SpatialDropout2D(0.3),

    Conv2D(128, (3, 3), activation='relu'),
    BatchNormalization(),
    MaxPooling2D((2, 2)),
    SpatialDropout2D(0.3),

    Flatten(),
    Dense(128, activation='relu'),
    Dropout(0.5),  # Standard Dropout for dense layers
    Dense(12, activation='softmax')  # 12 output units for 12 classes
])

# Compile the enhanced model
enhanced_model.compile(optimizer='adam',␣
 ↪loss='sparse_categorical_crossentropy', metrics=['accuracy'])
```

```
# Display model summary
enhanced_model.summary()
```

```
Model: "sequential_2"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_6 (Conv2D)            (None, 62, 62, 32)        896
_________________________________________________________________
batch_normalization_3 (Batch (None, 62, 62, 32)        128
_________________________________________________________________
max_pooling2d_6 (MaxPooling2 (None, 31, 31, 32)        0
_________________________________________________________________
spatial_dropout2d_3 (Spatial (None, 31, 31, 32)        0
_________________________________________________________________
conv2d_7 (Conv2D)            (None, 29, 29, 64)        18,496
_________________________________________________________________
batch_normalization_4 (Batch (None, 29, 29, 64)        256
_________________________________________________________________
max_pooling2d_7 (MaxPooling2 (None, 14, 14, 64)        0
_________________________________________________________________
spatial_dropout2d_4 (Spatial (None, 14, 14, 64)        0
_________________________________________________________________
conv2d_8 (Conv2D)            (None, 12, 12, 128)       73,856
_________________________________________________________________
batch_normalization_5 (Batch (None, 12, 12, 128)       512
```

```
(BatchNormalization)                                                    ␣
↪
max_pooling2d_8 (MaxPooling2D)          (None, 6, 6, 128)               ␣
↪ 0
spatial_dropout2d_5                     (None, 6, 6, 128)               ␣
↪ 0
(SpatialDropout2D)                                                      ␣
↪
flatten_2 (Flatten)                     (None, 4608)                    ␣
↪ 0
dense_4 (Dense)                         (None, 128)                     ␣
↪589,952
dropout_2 (Dropout)                     (None, 128)                     ␣
↪ 0
dense_5 (Dense)                         (None, 12)                      ␣
↪1,548
```

Total params: 685,644 (2.62 MB)

Trainable params: 685,196 (2.61 MB)

Non-trainable params: 448 (1.75 KB)

4.3 4.3 Train the Enhanced Model with Data Augmentation

Reference: The training with data augmentation is based on CIFAR_10_CNN_Sequential_Model, where augmented data is used to improve model generalization.

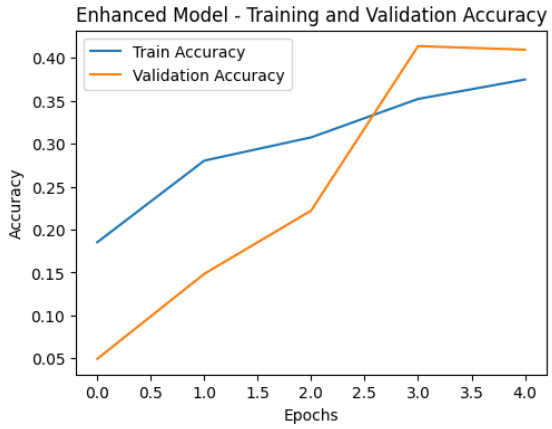
[24]:
```
# Train the model with data augmentation
history_enhanced = enhanced_model.fit(
    datagen.flow(X_train, y_train, batch_size=32),
    validation_data=(X_val, y_val),
    epochs=10,
    callbacks=[early_stopping]
)
```

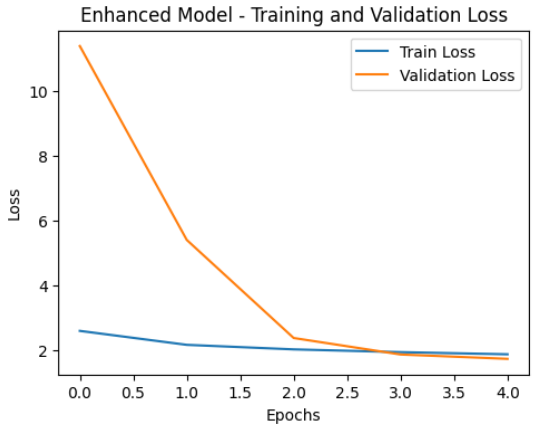
```
Epoch 1/10
119/119             18s 102ms/step -
```

```
accuracy: 0.1573 - loss: 3.0819 - val_accuracy: 0.0495 - val_loss: 11.4028
Epoch 2/10
119/119             7s 61ms/step -
accuracy: 0.2656 - loss: 2.2034 - val_accuracy: 0.1484 - val_loss: 5.4004
Epoch 3/10
119/119             7s 59ms/step -
accuracy: 0.3015 - loss: 2.0311 - val_accuracy: 0.2221 - val_loss: 2.3632
Epoch 4/10
119/119             7s 59ms/step -
accuracy: 0.3528 - loss: 1.9148 - val_accuracy: 0.4137 - val_loss: 1.8522
Epoch 5/10
119/119             5s 44ms/step -
accuracy: 0.3575 - loss: 1.9069 - val_accuracy: 0.4095 - val_loss: 1.7177
```

4.4 4.4 Plot Accuracy and Loss Curves

[25]:
```
# Plot training & validation accuracy and loss for the enhanced model
plt.figure(figsize=(12, 4))

# Accuracy plot
plt.subplot(1, 2, 1)
plt.plot(history_enhanced.history['accuracy'], label='Train Accuracy')
plt.plot(history_enhanced.history['val_accuracy'], label='Validation Accuracy')
plt.title('Enhanced Model - Training and Validation Accuracy')
plt.xlabel('Epochs')
plt.ylabel('Accuracy')
plt.legend()

# Loss plot
plt.subplot(1, 2, 2)
plt.plot(history_enhanced.history['loss'], label='Train Loss')
plt.plot(history_enhanced.history['val_loss'], label='Validation Loss')
plt.title('Enhanced Model - Training and Validation Loss')
plt.xlabel('Epochs')
plt.ylabel('Loss')
plt.legend()

plt.show()
```

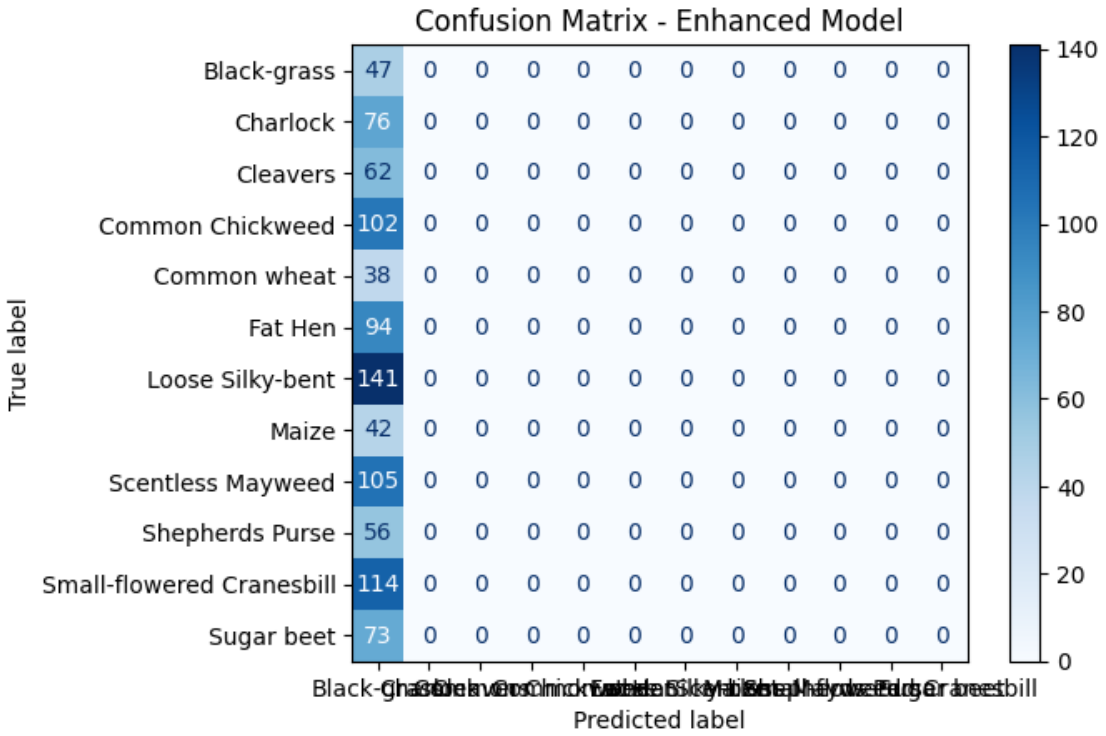




4.5 4.5 Evaluate the Enhanced Model with a Confusion Matrix and Classification Report

[26]:
```
# Predict on the validation set with the enhanced model
y_pred_enhanced = np.argmax(enhanced_model.predict(X_val), axis=1)

# Confusion matrix
cm_enhanced = confusion_matrix(y_val, y_pred_enhanced)
disp = ConfusionMatrixDisplay(confusion_matrix=cm_enhanced,␣
 ↪display_labels=label_encoder.classes_)
disp.plot(cmap=plt.cm.Blues)
plt.title('Confusion Matrix - Enhanced Model')
plt.show()

# Print classification report
print(classification_report(y_val, y_pred_enhanced, target_names=label_encoder.
 ↪classes_))
```

```
30/30              1s 14ms/step
```



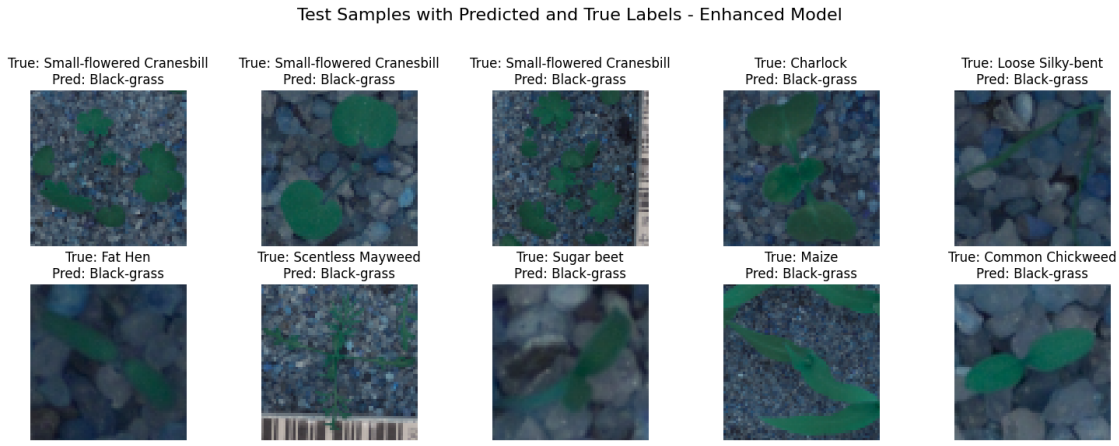
	precision	recall	f1-score	support
Black-grass	0.05	1.00	0.09	47
Charlock	0.00	0.00	0.00	76
Cleavers	0.00	0.00	0.00	62
Common Chickweed	0.00	0.00	0.00	102
Common wheat	0.00	0.00	0.00	38
Fat Hen	0.00	0.00	0.00	94
Loose Silky-bent	0.00	0.00	0.00	141
Maize	0.00	0.00	0.00	42
Scentless Mayweed	0.00	0.00	0.00	105
Shepherds Purse	0.00	0.00	0.00	56
Small-flowered Cranesbill	0.00	0.00	0.00	114
Sugar beet	0.00	0.00	0.00	73
accuracy			0.05	950
macro avg	0.00	0.08	0.01	950
weighted avg	0.00	0.05	0.00	950

```
/usr/local/lib/python3.10/dist-packages/sklearn/metrics/_classification.py:1531:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0 in labels
with no predicted samples. Use `zero_division` parameter to control this
behavior.
```

```
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
/usr/local/lib/python3.10/dist-packages/sklearn/metrics/_classification.py:1531:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0 in labels
with no predicted samples. Use `zero_division` parameter to control this
behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
/usr/local/lib/python3.10/dist-packages/sklearn/metrics/_classification.py:1531:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0 in labels
with no predicted samples. Use `zero_division` parameter to control this
behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
```

4.6 4.6 Visualize Test Samples with Predictions (Enhanced Model)

[27]:
```
# Visualize a few test samples with their predicted and true labels for the␣
 ↪enhanced model
fig, axes = plt.subplots(2, 5, figsize=(15, 6))
fig.suptitle('Test Samples with Predicted and True Labels - Enhanced Model',␣
 ↪fontsize=16)

sample_indices = random.sample(range(len(X_val)), 10)
for idx, ax in zip(sample_indices, axes.flat):
    ax.imshow(X_val[idx])
    ax.set_title(f"True: {label_encoder.
 ↪inverse_transform([y_val[idx]])[0]}\nPred: {label_encoder.
 ↪inverse_transform([y_pred_enhanced[idx]])[0]}")
    ax.axis('off')

plt.tight_layout(rect=[0, 0.03, 1, 0.95])
plt.show()
```



5 Step 5: Model 3 - Transfer Learning with Pre-trained Models

5.1 5.1 Load and Configure Pre-trained Models (VGG16 and ResNet50)

[28]:
```
from tensorflow.keras.applications import VGG16, ResNet50
from tensorflow.keras.layers import GlobalAveragePooling2D, Dense, Dropout
from tensorflow.keras.models import Model

# Load VGG16 with pre-trained weights, excluding the top layer
base_model_vgg = VGG16(weights='imagenet', include_top=False, input_shape=(64,␣
↪64, 3))
for layer in base_model_vgg.layers:
    layer.trainable = False  # Freeze the layers to retain learned features

# Add custom layers on top of VGG16
x = base_model_vgg.output
x = GlobalAveragePooling2D()(x)
x = Dense(128, activation='relu')(x)
x = Dropout(0.5)(x)  # Regularization layer
output = Dense(12, activation='softmax')(x)  # 12 classes for 12 plant species
vgg_model = Model(inputs=base_model_vgg.input, outputs=output)

# Compile the VGG16 model
vgg_model.compile(optimizer='adam', loss='sparse_categorical_crossentropy',␣
↪metrics=['accuracy'])
vgg_model.summary()
```

```
Downloading data from https://storage.googleapis.com/tensorflow/keras-
applications/vgg16/vgg16_weights_tf_dim_ordering_tf_kernels_notop.h5
58889256/58889256              0s
0us/step
```

Model: "functional_3"

Layer (type)	Output Shape	Param #
input_layer_3 (InputLayer)	(None, 64, 64, 3)	0
block1_conv1 (Conv2D)	(None, 64, 64, 64)	1,792
block1_conv2 (Conv2D)	(None, 64, 64, 64)	36,928

```
block1_pool (MaxPooling2D)           (None, 32, 32, 64)                ␣
↪ 0

block2_conv1 (Conv2D)                (None, 32, 32, 128)                ␣
↪73,856

block2_conv2 (Conv2D)                (None, 32, 32, 128)                ␣
↪147,584

block2_pool (MaxPooling2D)           (None, 16, 16, 128)                ␣
↪ 0

block3_conv1 (Conv2D)                (None, 16, 16, 256)                ␣
↪295,168

block3_conv2 (Conv2D)                (None, 16, 16, 256)                ␣
↪590,080

block3_conv3 (Conv2D)                (None, 16, 16, 256)                ␣
↪590,080

block3_pool (MaxPooling2D)           (None, 8, 8, 256)                ␣
↪ 0

block4_conv1 (Conv2D)                (None, 8, 8, 512)                ␣
↪1,180,160

block4_conv2 (Conv2D)                (None, 8, 8, 512)                ␣
↪2,359,808

block4_conv3 (Conv2D)                (None, 8, 8, 512)                ␣
↪2,359,808

block4_pool (MaxPooling2D)           (None, 4, 4, 512)                ␣
↪ 0

block5_conv1 (Conv2D)                (None, 4, 4, 512)                ␣
↪2,359,808

block5_conv2 (Conv2D)                (None, 4, 4, 512)                ␣
↪2,359,808

block5_conv3 (Conv2D)                (None, 4, 4, 512)                ␣
↪2,359,808

block5_pool (MaxPooling2D)           (None, 2, 2, 512)                ␣
↪ 0
```

```
global_average_pooling2d              (None, 512)                 ␣
↪  0
(GlobalAveragePooling2D)                                          ␣
↪

dense_6 (Dense)                       (None, 128)                 ␣
↪65,664

dropout_3 (Dropout)                   (None, 128)                 ␣
↪  0

dense_7 (Dense)                       (None, 12)                  ␣
↪1,548


Total params: 14,781,900 (56.39 MB)

Trainable params: 67,212 (262.55 KB)

Non-trainable params: 14,714,688 (56.13 MB)
```

[29]:
```
# Load ResNet50 with pre-trained weights, excluding the top layer
base_model_resnet = ResNet50(weights='imagenet', include_top=False,␣
 ↪input_shape=(64, 64, 3))
for layer in base_model_resnet.layers:
    layer.trainable = False  # Freeze the layers

# Add custom layers on top of ResNet50
x = base_model_resnet.output
x = GlobalAveragePooling2D()(x)
x = Dense(128, activation='relu')(x)
x = Dropout(0.5)(x)
output = Dense(12, activation='softmax')(x)
resnet_model = Model(inputs=base_model_resnet.input, outputs=output)

# Compile the ResNet50 model
resnet_model.compile(optimizer='adam', loss='sparse_categorical_crossentropy',␣
 ↪metrics=['accuracy'])
resnet_model.summary()
```

```
Downloading data from https://storage.googleapis.com/tensorflow/keras-
applications/resnet/resnet50_weights_tf_dim_ordering_tf_kernels_notop.h5
94765736/94765736             1s
0us/step
```

```
Model: "functional_4"
_________________________________________________________________
Layer (type)                 Output Shape              Param #   Connected
↪to
=================================================================
input_layer_4                (None, 64, 64, 3)         0         -
↪
(InputLayer)
↪
_________________________________________________________________
conv1_pad (ZeroPadding2D)    (None, 70, 70, 3)         0
↪input_layer_4[0][0]
_________________________________________________________________
conv1_conv (Conv2D)          (None, 32, 32, 64)        9,472
↪conv1_pad[0][0]
_________________________________________________________________
conv1_bn                     (None, 32, 32, 64)        256
↪conv1_conv[0][0]
(BatchNormalization)
↪
_________________________________________________________________
conv1_relu (Activation)      (None, 32, 32, 64)        0
↪conv1_bn[0][0]
_________________________________________________________________
pool1_pad (ZeroPadding2D)    (None, 34, 34, 64)        0
↪conv1_relu[0][0]
_________________________________________________________________
pool1_pool (MaxPooling2D)    (None, 16, 16, 64)        0
↪pool1_pad[0][0]
_________________________________________________________________
conv2_block1_1_conv          (None, 16, 16, 64)        4,160
↪pool1_pool[0][0]
(Conv2D)
↪
_________________________________________________________________
conv2_block1_1_bn            (None, 16, 16, 64)        256
↪conv2_block1_1_conv[0…
(BatchNormalization)
↪
_________________________________________________________________
conv2_block1_1_relu          (None, 16, 16, 64)        0
↪conv2_block1_1_bn[0][…
(Activation)
↪
_________________________________________________________________
```

```
conv2_block1_2_conv          (None, 16, 16, 64)          36,928 ␣
↪conv2_block1_1_relu[0…
(Conv2D)                                                        ␣
↪

conv2_block1_2_bn            (None, 16, 16, 64)             256 ␣
↪conv2_block1_2_conv[0…
(BatchNormalization)                                            ␣
↪

conv2_block1_2_relu          (None, 16, 16, 64)               0 ␣
↪conv2_block1_2_bn[0][…
(Activation)                                                    ␣
↪

conv2_block1_0_conv          (None, 16, 16, 256)         16,640 ␣
↪pool1_pool[0][0]
(Conv2D)                                                        ␣
↪

conv2_block1_3_conv          (None, 16, 16, 256)         16,640 ␣
↪conv2_block1_2_relu[0…
(Conv2D)                                                        ␣
↪

conv2_block1_0_bn            (None, 16, 16, 256)          1,024 ␣
↪conv2_block1_0_conv[0…
(BatchNormalization)                                            ␣
↪

conv2_block1_3_bn            (None, 16, 16, 256)          1,024 ␣
↪conv2_block1_3_conv[0…
(BatchNormalization)                                            ␣
↪

conv2_block1_add (Add)       (None, 16, 16, 256)              0 ␣
↪conv2_block1_0_bn[0][…
                                                                ␣
↪conv2_block1_3_bn[0][…

conv2_block1_out             (None, 16, 16, 256)              0 ␣
↪conv2_block1_add[0][0]
(Activation)                                                    ␣
↪
```

```
conv2_block2_1_conv         (None, 16, 16, 64)          16,448 ␣
↪conv2_block1_out[0][0]
(Conv2D)                                                   ␣
↪

conv2_block2_1_bn           (None, 16, 16, 64)             256 ␣
↪conv2_block2_1_conv[0…
(BatchNormalization)                                       ␣
↪

conv2_block2_1_relu         (None, 16, 16, 64)               0 ␣
↪conv2_block2_1_bn[0][…
(Activation)                                               ␣
↪

conv2_block2_2_conv         (None, 16, 16, 64)          36,928 ␣
↪conv2_block2_1_relu[0…
(Conv2D)                                                   ␣
↪

conv2_block2_2_bn           (None, 16, 16, 64)             256 ␣
↪conv2_block2_2_conv[0…
(BatchNormalization)                                       ␣
↪

conv2_block2_2_relu         (None, 16, 16, 64)               0 ␣
↪conv2_block2_2_bn[0][…
(Activation)                                               ␣
↪

conv2_block2_3_conv         (None, 16, 16, 256)         16,640 ␣
↪conv2_block2_2_relu[0…
(Conv2D)                                                   ␣
↪

conv2_block2_3_bn           (None, 16, 16, 256)          1,024 ␣
↪conv2_block2_3_conv[0…
(BatchNormalization)                                       ␣
↪

conv2_block2_add (Add)      (None, 16, 16, 256)              0 ␣
↪conv2_block1_out[0][0…
                                                           ␣
↪conv2_block2_3_bn[0][…
```

```
conv2_block2_out            (None, 16, 16, 256)                0 ␣
↪conv2_block2_add[0][0]
(Activation)                                                      ␣
↪

conv2_block3_1_conv         (None, 16, 16, 64)             16,448 ␣
↪conv2_block2_out[0][0]
(Conv2D)                                                          ␣
↪

conv2_block3_1_bn           (None, 16, 16, 64)                256 ␣
↪conv2_block3_1_conv[0…
(BatchNormalization)                                              ␣
↪

conv2_block3_1_relu         (None, 16, 16, 64)                 0 ␣
↪conv2_block3_1_bn[0][…
(Activation)                                                      ␣
↪

conv2_block3_2_conv         (None, 16, 16, 64)             36,928 ␣
↪conv2_block3_1_relu[0…
(Conv2D)                                                          ␣
↪

conv2_block3_2_bn           (None, 16, 16, 64)                256 ␣
↪conv2_block3_2_conv[0…
(BatchNormalization)                                              ␣
↪

conv2_block3_2_relu         (None, 16, 16, 64)                 0 ␣
↪conv2_block3_2_bn[0][…
(Activation)                                                      ␣
↪

conv2_block3_3_conv         (None, 16, 16, 256)            16,640 ␣
↪conv2_block3_2_relu[0…
(Conv2D)                                                          ␣
↪

conv2_block3_3_bn           (None, 16, 16, 256)             1,024 ␣
↪conv2_block3_3_conv[0…
(BatchNormalization)                                              ␣
↪
```

```
conv2_block3_add (Add)          (None, 16, 16, 256)              0 ␣
↪conv2_block2_out[0][0…
                                                                  ␣
↪conv2_block3_3_bn[0][…

conv2_block3_out                (None, 16, 16, 256)              0 ␣
↪conv2_block3_add[0][0]
(Activation)                                                      ␣
↪

conv3_block1_1_conv             (None, 8, 8, 128)           32,896 ␣
↪conv2_block3_out[0][0]
(Conv2D)                                                          ␣
↪

conv3_block1_1_bn               (None, 8, 8, 128)              512 ␣
↪conv3_block1_1_conv[0…
(BatchNormalization)                                              ␣
↪

conv3_block1_1_relu             (None, 8, 8, 128)                0 ␣
↪conv3_block1_1_bn[0][…
(Activation)                                                      ␣
↪

conv3_block1_2_conv             (None, 8, 8, 128)          147,584 ␣
↪conv3_block1_1_relu[0…
(Conv2D)                                                          ␣
↪

conv3_block1_2_bn               (None, 8, 8, 128)              512 ␣
↪conv3_block1_2_conv[0…
(BatchNormalization)                                              ␣
↪

conv3_block1_2_relu             (None, 8, 8, 128)                0 ␣
↪conv3_block1_2_bn[0][…
(Activation)                                                      ␣
↪

conv3_block1_0_conv             (None, 8, 8, 512)          131,584 ␣
↪conv2_block3_out[0][0]
(Conv2D)                                                          ␣
↪
```

```
conv3_block1_3_conv          (None, 8, 8, 512)          66,048 ␣
↪conv3_block1_2_relu[0…
(Conv2D)                                                       ␣
↪

conv3_block1_0_bn            (None, 8, 8, 512)           2,048 ␣
↪conv3_block1_0_conv[0…
(BatchNormalization)                                           ␣
↪

conv3_block1_3_bn            (None, 8, 8, 512)           2,048 ␣
↪conv3_block1_3_conv[0…
(BatchNormalization)                                           ␣
↪

conv3_block1_add (Add)       (None, 8, 8, 512)               0 ␣
↪conv3_block1_0_bn[0][…
                                                               ␣
↪conv3_block1_3_bn[0][…

conv3_block1_out             (None, 8, 8, 512)               0 ␣
↪conv3_block1_add[0][0]
(Activation)                                                   ␣
↪

conv3_block2_1_conv          (None, 8, 8, 128)          65,664 ␣
↪conv3_block1_out[0][0]
(Conv2D)                                                       ␣
↪

conv3_block2_1_bn            (None, 8, 8, 128)             512 ␣
↪conv3_block2_1_conv[0…
(BatchNormalization)                                           ␣
↪

conv3_block2_1_relu          (None, 8, 8, 128)               0 ␣
↪conv3_block2_1_bn[0][…
(Activation)                                                   ␣
↪

conv3_block2_2_conv          (None, 8, 8, 128)         147,584 ␣
↪conv3_block2_1_relu[0…
(Conv2D)                                                       ␣
↪
```

```
conv3_block2_2_bn           (None, 8, 8, 128)         512
↪conv3_block2_2_conv[0…
(BatchNormalization)
↪

conv3_block2_2_relu         (None, 8, 8, 128)         0
↪conv3_block2_2_bn[0][…
(Activation)
↪

conv3_block2_3_conv         (None, 8, 8, 512)         66,048
↪conv3_block2_2_relu[0…
(Conv2D)
↪

conv3_block2_3_bn           (None, 8, 8, 512)         2,048
↪conv3_block2_3_conv[0…
(BatchNormalization)
↪

conv3_block2_add (Add)      (None, 8, 8, 512)         0
↪conv3_block1_out[0][0…

↪conv3_block2_3_bn[0][…

conv3_block2_out            (None, 8, 8, 512)         0
↪conv3_block2_add[0][0]
(Activation)
↪

conv3_block3_1_conv         (None, 8, 8, 128)         65,664
↪conv3_block2_out[0][0]
(Conv2D)
↪

conv3_block3_1_bn           (None, 8, 8, 128)         512
↪conv3_block3_1_conv[0…
(BatchNormalization)
↪

conv3_block3_1_relu         (None, 8, 8, 128)         0
↪conv3_block3_1_bn[0][…
(Activation)
↪
```

```
conv3_block3_2_conv          (None, 8, 8, 128)          147,584 ␣
↪conv3_block3_1_relu[0…
(Conv2D)                                                        ␣
↪

conv3_block3_2_bn            (None, 8, 8, 128)              512 ␣
↪conv3_block3_2_conv[0…
(BatchNormalization)                                            ␣
↪

conv3_block3_2_relu          (None, 8, 8, 128)                0 ␣
↪conv3_block3_2_bn[0][…
(Activation)                                                    ␣
↪

conv3_block3_3_conv          (None, 8, 8, 512)           66,048 ␣
↪conv3_block3_2_relu[0…
(Conv2D)                                                        ␣
↪

conv3_block3_3_bn            (None, 8, 8, 512)            2,048 ␣
↪conv3_block3_3_conv[0…
(BatchNormalization)                                            ␣
↪

conv3_block3_add (Add)       (None, 8, 8, 512)                0 ␣
↪conv3_block2_out[0][0…
                                                                ␣
↪conv3_block3_3_bn[0][…

conv3_block3_out             (None, 8, 8, 512)                0 ␣
↪conv3_block3_add[0][0]
(Activation)                                                    ␣
↪

conv3_block4_1_conv          (None, 8, 8, 128)           65,664 ␣
↪conv3_block3_out[0][0]
(Conv2D)                                                        ␣
↪

conv3_block4_1_bn            (None, 8, 8, 128)              512 ␣
↪conv3_block4_1_conv[0…
(BatchNormalization)                                            ␣
↪
```

```
conv3_block4_1_relu         (None, 8, 8, 128)                 0 ␣
↪conv3_block4_1_bn[0][…
(Activation)                                                    ␣
↪

conv3_block4_2_conv         (None, 8, 8, 128)           147,584 ␣
↪conv3_block4_1_relu[0…
(Conv2D)                                                        ␣
↪

conv3_block4_2_bn           (None, 8, 8, 128)               512 ␣
↪conv3_block4_2_conv[0…
(BatchNormalization)                                            ␣
↪

conv3_block4_2_relu         (None, 8, 8, 128)                 0 ␣
↪conv3_block4_2_bn[0][…
(Activation)                                                    ␣
↪

conv3_block4_3_conv         (None, 8, 8, 512)            66,048 ␣
↪conv3_block4_2_relu[0…
(Conv2D)                                                        ␣
↪

conv3_block4_3_bn           (None, 8, 8, 512)             2,048 ␣
↪conv3_block4_3_conv[0…
(BatchNormalization)                                            ␣
↪

conv3_block4_add (Add)      (None, 8, 8, 512)                 0 ␣
↪conv3_block3_out[0][0…
                                                                ␣
↪conv3_block4_3_bn[0][…

conv3_block4_out            (None, 8, 8, 512)                 0 ␣
↪conv3_block4_add[0][0]
(Activation)                                                    ␣
↪

conv4_block1_1_conv         (None, 4, 4, 256)           131,328 ␣
↪conv3_block4_out[0][0]
(Conv2D)                                                        ␣
↪
```

```
conv4_block1_1_bn          (None, 4, 4, 256)          1,024 ␣
↪conv4_block1_1_conv[0…
(BatchNormalization)                                     ␣
↪

conv4_block1_1_relu        (None, 4, 4, 256)              0 ␣
↪conv4_block1_1_bn[0][…
(Activation)                                             ␣
↪

conv4_block1_2_conv        (None, 4, 4, 256)        590,080 ␣
↪conv4_block1_1_relu[0…
(Conv2D)                                                 ␣
↪

conv4_block1_2_bn          (None, 4, 4, 256)          1,024 ␣
↪conv4_block1_2_conv[0…
(BatchNormalization)                                     ␣
↪

conv4_block1_2_relu        (None, 4, 4, 256)              0 ␣
↪conv4_block1_2_bn[0][…
(Activation)                                             ␣
↪

conv4_block1_0_conv        (None, 4, 4, 1024)       525,312 ␣
↪conv3_block4_out[0][0]
(Conv2D)                                                 ␣
↪

conv4_block1_3_conv        (None, 4, 4, 1024)       263,168 ␣
↪conv4_block1_2_relu[0…
(Conv2D)                                                 ␣
↪

conv4_block1_0_bn          (None, 4, 4, 1024)         4,096 ␣
↪conv4_block1_0_conv[0…
(BatchNormalization)                                     ␣
↪

conv4_block1_3_bn          (None, 4, 4, 1024)         4,096 ␣
↪conv4_block1_3_conv[0…
(BatchNormalization)                                     ␣
↪
```

```
conv4_block1_add (Add)          (None, 4, 4, 1024)                  0 ␣
↪conv4_block1_0_bn[0][…
                                                                      ␣
↪conv4_block1_3_bn[0][…

conv4_block1_out                (None, 4, 4, 1024)                  0 ␣
↪conv4_block1_add[0][0]
(Activation)                                                          ␣
↪

conv4_block2_1_conv             (None, 4, 4, 256)             262,400 ␣
↪conv4_block1_out[0][0]
(Conv2D)                                                              ␣
↪

conv4_block2_1_bn               (None, 4, 4, 256)               1,024 ␣
↪conv4_block2_1_conv[0…
(BatchNormalization)                                                  ␣
↪

conv4_block2_1_relu             (None, 4, 4, 256)                   0 ␣
↪conv4_block2_1_bn[0][…
(Activation)                                                          ␣
↪

conv4_block2_2_conv             (None, 4, 4, 256)             590,080 ␣
↪conv4_block2_1_relu[0…
(Conv2D)                                                              ␣
↪

conv4_block2_2_bn               (None, 4, 4, 256)               1,024 ␣
↪conv4_block2_2_conv[0…
(BatchNormalization)                                                  ␣
↪

conv4_block2_2_relu             (None, 4, 4, 256)                   0 ␣
↪conv4_block2_2_bn[0][…
(Activation)                                                          ␣
↪

conv4_block2_3_conv             (None, 4, 4, 1024)            263,168 ␣
↪conv4_block2_2_relu[0…
(Conv2D)                                                              ␣
↪
```

```
conv4_block2_3_bn           (None, 4, 4, 1024)          4,096 ␣
↪conv4_block2_3_conv[0…
(BatchNormalization)                                          ␣
↪

conv4_block2_add (Add)      (None, 4, 4, 1024)              0 ␣
↪conv4_block1_out[0][0…
                                                              ␣
↪conv4_block2_3_bn[0][…

conv4_block2_out            (None, 4, 4, 1024)              0 ␣
↪conv4_block2_add[0][0]
(Activation)                                                  ␣
↪

conv4_block3_1_conv         (None, 4, 4, 256)         262,400 ␣
↪conv4_block2_out[0][0]
(Conv2D)                                                      ␣
↪

conv4_block3_1_bn           (None, 4, 4, 256)           1,024 ␣
↪conv4_block3_1_conv[0…
(BatchNormalization)                                          ␣
↪

conv4_block3_1_relu         (None, 4, 4, 256)               0 ␣
↪conv4_block3_1_bn[0][…
(Activation)                                                  ␣
↪

conv4_block3_2_conv         (None, 4, 4, 256)         590,080 ␣
↪conv4_block3_1_relu[0…
(Conv2D)                                                      ␣
↪

conv4_block3_2_bn           (None, 4, 4, 256)           1,024 ␣
↪conv4_block3_2_conv[0…
(BatchNormalization)                                          ␣
↪

conv4_block3_2_relu         (None, 4, 4, 256)               0 ␣
↪conv4_block3_2_bn[0][…
(Activation)                                                  ␣
↪
```

```
conv4_block3_3_conv          (None, 4, 4, 1024)          263,168 ␣
↪conv4_block3_2_relu[0…
(Conv2D)                                                         ␣
↪

conv4_block3_3_bn            (None, 4, 4, 1024)            4,096 ␣
↪conv4_block3_3_conv[0…
(BatchNormalization)                                             ␣
↪

conv4_block3_add (Add)       (None, 4, 4, 1024)                0 ␣
↪conv4_block2_out[0][0…
                                                                 ␣
↪conv4_block3_3_bn[0][…

conv4_block3_out             (None, 4, 4, 1024)                0 ␣
↪conv4_block3_add[0][0]
(Activation)                                                     ␣
↪

conv4_block4_1_conv          (None, 4, 4, 256)           262,400 ␣
↪conv4_block3_out[0][0]
(Conv2D)                                                         ␣
↪

conv4_block4_1_bn            (None, 4, 4, 256)             1,024 ␣
↪conv4_block4_1_conv[0…
(BatchNormalization)                                             ␣
↪

conv4_block4_1_relu          (None, 4, 4, 256)                 0 ␣
↪conv4_block4_1_bn[0][…
(Activation)                                                     ␣
↪

conv4_block4_2_conv          (None, 4, 4, 256)           590,080 ␣
↪conv4_block4_1_relu[0…
(Conv2D)                                                         ␣
↪

conv4_block4_2_bn            (None, 4, 4, 256)             1,024 ␣
↪conv4_block4_2_conv[0…
(BatchNormalization)                                             ␣
↪
```

```
conv4_block4_2_relu         (None, 4, 4, 256)                 0 ␣
↪conv4_block4_2_bn[0][…
(Activation)                                                    ␣
↪

conv4_block4_3_conv         (None, 4, 4, 1024)          263,168 ␣
↪conv4_block4_2_relu[0…
(Conv2D)                                                        ␣
↪

conv4_block4_3_bn           (None, 4, 4, 1024)            4,096 ␣
↪conv4_block4_3_conv[0…
(BatchNormalization)                                            ␣
↪

conv4_block4_add (Add)      (None, 4, 4, 1024)                0 ␣
↪conv4_block3_out[0][0…
                                                                ␣
↪conv4_block4_3_bn[0][…

conv4_block4_out            (None, 4, 4, 1024)                0 ␣
↪conv4_block4_add[0][0]
(Activation)                                                    ␣
↪

conv4_block5_1_conv         (None, 4, 4, 256)           262,400 ␣
↪conv4_block4_out[0][0]
(Conv2D)                                                        ␣
↪

conv4_block5_1_bn           (None, 4, 4, 256)             1,024 ␣
↪conv4_block5_1_conv[0…
(BatchNormalization)                                            ␣
↪

conv4_block5_1_relu         (None, 4, 4, 256)                 0 ␣
↪conv4_block5_1_bn[0][…
(Activation)                                                    ␣
↪

conv4_block5_2_conv         (None, 4, 4, 256)           590,080 ␣
↪conv4_block5_1_relu[0…
(Conv2D)                                                        ␣
↪
```

```
conv4_block5_2_bn           (None, 4, 4, 256)          1,024 ␣
↪conv4_block5_2_conv[0…
(BatchNormalization)                                      ␣
↪

conv4_block5_2_relu         (None, 4, 4, 256)              0 ␣
↪conv4_block5_2_bn[0][…
(Activation)                                              ␣
↪

conv4_block5_3_conv         (None, 4, 4, 1024)       263,168 ␣
↪conv4_block5_2_relu[0…
(Conv2D)                                                  ␣
↪

conv4_block5_3_bn           (None, 4, 4, 1024)         4,096 ␣
↪conv4_block5_3_conv[0…
(BatchNormalization)                                      ␣
↪

conv4_block5_add (Add)      (None, 4, 4, 1024)             0 ␣
↪conv4_block4_out[0][0…
                                                          ␣
↪conv4_block5_3_bn[0][…

conv4_block5_out            (None, 4, 4, 1024)             0 ␣
↪conv4_block5_add[0][0]
(Activation)                                              ␣
↪

conv4_block6_1_conv         (None, 4, 4, 256)        262,400 ␣
↪conv4_block5_out[0][0]
(Conv2D)                                                  ␣
↪

conv4_block6_1_bn           (None, 4, 4, 256)          1,024 ␣
↪conv4_block6_1_conv[0…
(BatchNormalization)                                      ␣
↪

conv4_block6_1_relu         (None, 4, 4, 256)              0 ␣
↪conv4_block6_1_bn[0][…
(Activation)                                              ␣
↪
```

```
conv4_block6_2_conv          (None, 4, 4, 256)         590,080
↪conv4_block6_1_relu[0…
(Conv2D)
↪

conv4_block6_2_bn            (None, 4, 4, 256)         1,024
↪conv4_block6_2_conv[0…
(BatchNormalization)
↪

conv4_block6_2_relu          (None, 4, 4, 256)         0
↪conv4_block6_2_bn[0][…
(Activation)
↪

conv4_block6_3_conv          (None, 4, 4, 1024)        263,168
↪conv4_block6_2_relu[0…
(Conv2D)
↪

conv4_block6_3_bn            (None, 4, 4, 1024)        4,096
↪conv4_block6_3_conv[0…
(BatchNormalization)
↪

conv4_block6_add (Add)       (None, 4, 4, 1024)        0
↪conv4_block5_out[0][0…

↪conv4_block6_3_bn[0][…

conv4_block6_out             (None, 4, 4, 1024)        0
↪conv4_block6_add[0][0]
(Activation)
↪

conv5_block1_1_conv          (None, 2, 2, 512)         524,800
↪conv4_block6_out[0][0]
(Conv2D)
↪

conv5_block1_1_bn            (None, 2, 2, 512)         2,048
↪conv5_block1_1_conv[0…
(BatchNormalization)
↪
```

```
conv5_block1_1_relu         (None, 2, 2, 512)                 0 ␣
↪conv5_block1_1_bn[0][…
(Activation)                                                    ␣
↪

conv5_block1_2_conv         (None, 2, 2, 512)           2,359,808 ␣
↪conv5_block1_1_relu[0…
(Conv2D)                                                        ␣
↪

conv5_block1_2_bn           (None, 2, 2, 512)               2,048 ␣
↪conv5_block1_2_conv[0…
(BatchNormalization)                                            ␣
↪

conv5_block1_2_relu         (None, 2, 2, 512)                 0 ␣
↪conv5_block1_2_bn[0][…
(Activation)                                                    ␣
↪

conv5_block1_0_conv         (None, 2, 2, 2048)          2,099,200 ␣
↪conv4_block6_out[0][0]
(Conv2D)                                                        ␣
↪

conv5_block1_3_conv         (None, 2, 2, 2048)          1,050,624 ␣
↪conv5_block1_2_relu[0…
(Conv2D)                                                        ␣
↪

conv5_block1_0_bn           (None, 2, 2, 2048)              8,192 ␣
↪conv5_block1_0_conv[0…
(BatchNormalization)                                            ␣
↪

conv5_block1_3_bn           (None, 2, 2, 2048)              8,192 ␣
↪conv5_block1_3_conv[0…
(BatchNormalization)                                            ␣
↪

conv5_block1_add (Add)      (None, 2, 2, 2048)                0 ␣
↪conv5_block1_0_bn[0][…
                                                                ␣
↪conv5_block1_3_bn[0][…
```

```
conv5_block1_out            (None, 2, 2, 2048)                0 ␣
↪conv5_block1_add[0][0]
(Activation)                                                    ␣
↪

conv5_block2_1_conv         (None, 2, 2, 512)           1,049,088 ␣
↪conv5_block1_out[0][0]
(Conv2D)                                                        ␣
↪

conv5_block2_1_bn           (None, 2, 2, 512)               2,048 ␣
↪conv5_block2_1_conv[0…
(BatchNormalization)                                            ␣
↪

conv5_block2_1_relu         (None, 2, 2, 512)                   0 ␣
↪conv5_block2_1_bn[0][…
(Activation)                                                    ␣
↪

conv5_block2_2_conv         (None, 2, 2, 512)           2,359,808 ␣
↪conv5_block2_1_relu[0…
(Conv2D)                                                        ␣
↪

conv5_block2_2_bn           (None, 2, 2, 512)               2,048 ␣
↪conv5_block2_2_conv[0…
(BatchNormalization)                                            ␣
↪

conv5_block2_2_relu         (None, 2, 2, 512)                   0 ␣
↪conv5_block2_2_bn[0][…
(Activation)                                                    ␣
↪

conv5_block2_3_conv         (None, 2, 2, 2048)          1,050,624 ␣
↪conv5_block2_2_relu[0…
(Conv2D)                                                        ␣
↪

conv5_block2_3_bn           (None, 2, 2, 2048)              8,192 ␣
↪conv5_block2_3_conv[0…
(BatchNormalization)                                            ␣
↪
```

```
conv5_block2_add (Add)          (None, 2, 2, 2048)                  0  ␣
↪conv5_block1_out[0][0…
                                                                       ␣
↪conv5_block2_3_bn[0][…

conv5_block2_out                (None, 2, 2, 2048)                  0  ␣
↪conv5_block2_add[0][0]
(Activation)                                                           ␣
↪

conv5_block3_1_conv             (None, 2, 2, 512)             1,049,088  ␣
↪conv5_block2_out[0][0]
(Conv2D)                                                               ␣
↪

conv5_block3_1_bn               (None, 2, 2, 512)                 2,048  ␣
↪conv5_block3_1_conv[0…
(BatchNormalization)                                                   ␣
↪

conv5_block3_1_relu             (None, 2, 2, 512)                   0  ␣
↪conv5_block3_1_bn[0][…
(Activation)                                                           ␣
↪

conv5_block3_2_conv             (None, 2, 2, 512)             2,359,808  ␣
↪conv5_block3_1_relu[0…
(Conv2D)                                                               ␣
↪

conv5_block3_2_bn               (None, 2, 2, 512)                 2,048  ␣
↪conv5_block3_2_conv[0…
(BatchNormalization)                                                   ␣
↪

conv5_block3_2_relu             (None, 2, 2, 512)                   0  ␣
↪conv5_block3_2_bn[0][…
(Activation)                                                           ␣
↪

conv5_block3_3_conv             (None, 2, 2, 2048)            1,050,624  ␣
↪conv5_block3_2_relu[0…
(Conv2D)                                                               ␣
↪
```

```
conv5_block3_3_bn           (None, 2, 2, 2048)          8,192 ␣
↪conv5_block3_3_conv[0…
(BatchNormalization)                                          ␣
↪

conv5_block3_add (Add)      (None, 2, 2, 2048)              0 ␣
↪conv5_block2_out[0][0…
                                                              ␣
↪conv5_block3_3_bn[0][…

conv5_block3_out            (None, 2, 2, 2048)              0 ␣
↪conv5_block3_add[0][0]
(Activation)                                                  ␣
↪

global_average_pooling2d…   (None, 2048)                    0 ␣
↪conv5_block3_out[0][0]
(GlobalAveragePooling2D)                                      ␣
↪

dense_8 (Dense)             (None, 128)               262,272 ␣
↪global_average_poolin…

dropout_4 (Dropout)         (None, 128)                     0 ␣
↪dense_8[0][0]

dense_9 (Dense)             (None, 12)                  1,548 ␣
↪dropout_4[0][0]


 Total params: 23,851,532 (90.99 MB)

 Trainable params: 263,820 (1.01 MB)

 Non-trainable params: 23,587,712 (89.98 MB)
```

5.2 5.2 Optional: Hyperparameter Tuning with Keras Tuner

[30]:
```
!pip install keras-tuner
```

```
Collecting keras-tuner
  Downloading keras_tuner-1.4.7-py3-none-any.whl.metadata (5.4 kB)
Requirement already satisfied: keras in /usr/local/lib/python3.10/dist-packages
(from keras-tuner) (3.4.1)
```

```
Requirement already satisfied: packaging in /usr/local/lib/python3.10/dist-
packages (from keras-tuner) (24.1)
Requirement already satisfied: requests in /usr/local/lib/python3.10/dist-
packages (from keras-tuner) (2.32.3)
Collecting kt-legacy (from keras-tuner)
  Downloading kt_legacy-1.0.5-py3-none-any.whl.metadata (221 bytes)
Requirement already satisfied: absl-py in /usr/local/lib/python3.10/dist-
packages (from keras->keras-tuner) (1.4.0)
Requirement already satisfied: numpy in /usr/local/lib/python3.10/dist-packages
(from keras->keras-tuner) (1.26.4)
Requirement already satisfied: rich in /usr/local/lib/python3.10/dist-packages
(from keras->keras-tuner) (13.9.3)
Requirement already satisfied: namex in /usr/local/lib/python3.10/dist-packages
(from keras->keras-tuner) (0.0.8)
Requirement already satisfied: h5py in /usr/local/lib/python3.10/dist-packages
(from keras->keras-tuner) (3.11.0)
Requirement already satisfied: optree in /usr/local/lib/python3.10/dist-packages
(from keras->keras-tuner) (0.13.0)
Requirement already satisfied: ml-dtypes in /usr/local/lib/python3.10/dist-
packages (from keras->keras-tuner) (0.4.1)
Requirement already satisfied: charset-normalizer<4,>=2 in
/usr/local/lib/python3.10/dist-packages (from requests->keras-tuner) (3.4.0)
Requirement already satisfied: idna<4,>=2.5 in /usr/local/lib/python3.10/dist-
packages (from requests->keras-tuner) (3.10)
Requirement already satisfied: urllib3<3,>=1.21.1 in
/usr/local/lib/python3.10/dist-packages (from requests->keras-tuner) (2.2.3)
Requirement already satisfied: certifi>=2017.4.17 in
/usr/local/lib/python3.10/dist-packages (from requests->keras-tuner) (2024.8.30)
Requirement already satisfied: typing-extensions>=4.5.0 in
/usr/local/lib/python3.10/dist-packages (from optree->keras->keras-tuner)
(4.12.2)
Requirement already satisfied: markdown-it-py>=2.2.0 in
/usr/local/lib/python3.10/dist-packages (from rich->keras->keras-tuner) (3.0.0)
Requirement already satisfied: pygments<3.0.0,>=2.13.0 in
/usr/local/lib/python3.10/dist-packages (from rich->keras->keras-tuner) (2.18.0)
Requirement already satisfied: mdurl~=0.1 in /usr/local/lib/python3.10/dist-
packages (from markdown-it-py>=2.2.0->rich->keras->keras-tuner) (0.1.2)
Downloading keras_tuner-1.4.7-py3-none-any.whl (129 kB)
                         129.1/129.1 kB
4.1 MB/s eta 0:00:00
Downloading kt_legacy-1.0.5-py3-none-any.whl (9.6 kB)
Installing collected packages: kt-legacy, keras-tuner
Successfully installed keras-tuner-1.4.7 kt-legacy-1.0.5
```

[31]:
```python
# If using Keras Tuner to optimize the dense layer in VGG16 or ResNet50 model
from kerastuner.tuners import RandomSearch
from tensorflow.keras.layers import Dense
```

```
def build_model(hp):
    # Base VGG16 model (or ResNet50) without the top layer
    base_model = VGG16(weights='imagenet', include_top=False, input_shape=(64,␣
 ↪64, 3))
    for layer in base_model.layers:
        layer.trainable = False

    # Add custom layers with tunable units in dense layer
    x = base_model.output
    x = GlobalAveragePooling2D()(x)
    x = Dense(hp.Int('units', min_value=64, max_value=256, step=64),␣
 ↪activation='relu')(x)
    x = Dropout(0.5)(x)
    output = Dense(12, activation='softmax')(x)
    model = Model(inputs=base_model.input, outputs=output)

    # Compile the model
    model.compile(optimizer='adam', loss='sparse_categorical_crossentropy',␣
 ↪metrics=['accuracy'])
    return model

# Instantiate the tuner
tuner = RandomSearch(build_model, objective='val_accuracy', max_trials=5,␣
 ↪executions_per_trial=1, directory='tuner_dir',␣
 ↪project_name='plant_classification')

# Run the tuner
tuner.search(X_train, y_train, epochs=10, validation_data=(X_val, y_val))
best_model = tuner.get_best_models(num_models=1)[0]
```

```
Trial 4 Complete [00h 00m 44s]
val_accuracy: 0.5073684453964233

Best val_accuracy So Far: 0.5789473652839661
Total elapsed time: 00h 03m 19s
```

```
/usr/local/lib/python3.10/dist-packages/keras/src/saving/saving_lib.py:576:
UserWarning: Skipping variable loading for optimizer 'adam', because it has 2
variables whereas the saved optimizer has 10 variables.
  saveable.load_own_variables(weights_store.get(inner_path))
```

5.3 5.3 Train Both Models (VGG16 and ResNet50)

[32]:
```
# Train VGG16 model
history_vgg = vgg_model.fit(
    datagen.flow(X_train, y_train, batch_size=32),
```

```
    validation_data=(X_val, y_val),
    epochs=20,
    callbacks=[early_stopping]
)
```

```
Epoch 1/20
```

```
/usr/local/lib/python3.10/dist-
packages/keras/src/trainers/data_adapters/py_dataset_adapter.py:121:
UserWarning: Your `PyDataset` class should call `super().__init__(**kwargs)` in
its constructor. `**kwargs` can include `workers`, `use_multiprocessing`,
`max_queue_size`. Do not pass these arguments to `fit()`, as they will be
ignored.
  self._warn_if_super_not_called()
```

```
119/119             13s 89ms/step -
accuracy: 0.1744 - loss: 2.4555 - val_accuracy: 0.3579 - val_loss: 2.0381
Epoch 2/20
119/119             15s 51ms/step -
accuracy: 0.3407 - loss: 2.0389 - val_accuracy: 0.4053 - val_loss: 1.8337
Epoch 3/20
119/119             8s 68ms/step -
accuracy: 0.3657 - loss: 1.8730 - val_accuracy: 0.4095 - val_loss: 1.7440
Epoch 4/20
119/119             7s 52ms/step -
accuracy: 0.3995 - loss: 1.7623 - val_accuracy: 0.4695 - val_loss: 1.6248
Epoch 5/20
119/119             9s 75ms/step -
accuracy: 0.4208 - loss: 1.7174 - val_accuracy: 0.4916 - val_loss: 1.5512
```

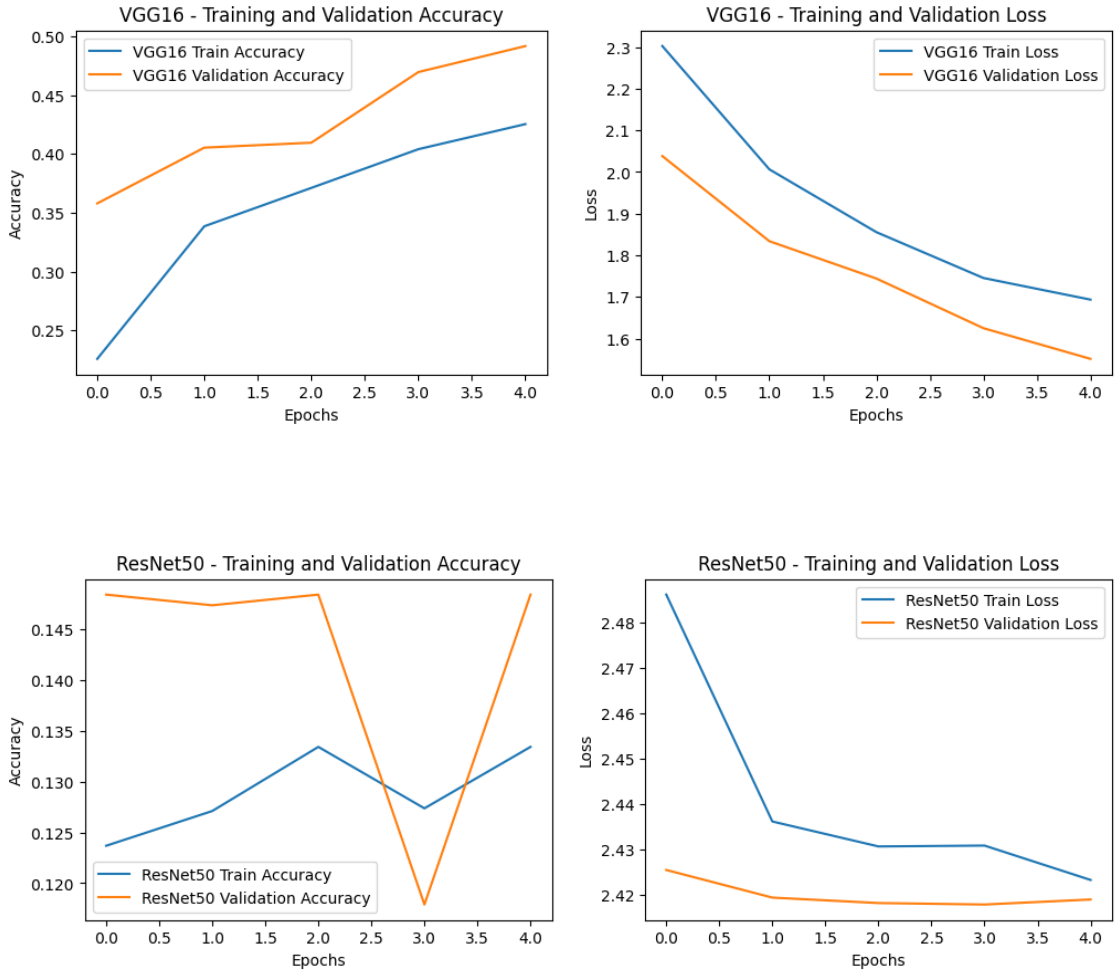
[33]:
```
# Train ResNet50 model
history_resnet = resnet_model.fit(
    datagen.flow(X_train, y_train, batch_size=32),
    validation_data=(X_val, y_val),
    epochs=20,
    callbacks=[early_stopping]
)
```

```
Epoch 1/20
119/119             31s 157ms/step -
accuracy: 0.1189 - loss: 2.5618 - val_accuracy: 0.1484 - val_loss: 2.4255
Epoch 2/20
119/119             25s 53ms/step -
accuracy: 0.1167 - loss: 2.4408 - val_accuracy: 0.1474 - val_loss: 2.4194
Epoch 3/20
119/119             12s 68ms/step -
accuracy: 0.1438 - loss: 2.4342 - val_accuracy: 0.1484 - val_loss: 2.4182
Epoch 4/20
119/119             8s 68ms/step -
```

```
accuracy: 0.1245 - loss: 2.4252 - val_accuracy: 0.1179 - val_loss: 2.4179
Epoch 5/20
119/119             7s 53ms/step -
accuracy: 0.1344 - loss: 2.4209 - val_accuracy: 0.1484 - val_loss: 2.4190
```

5.4 5.4 Plot Accuracy and Loss Curves

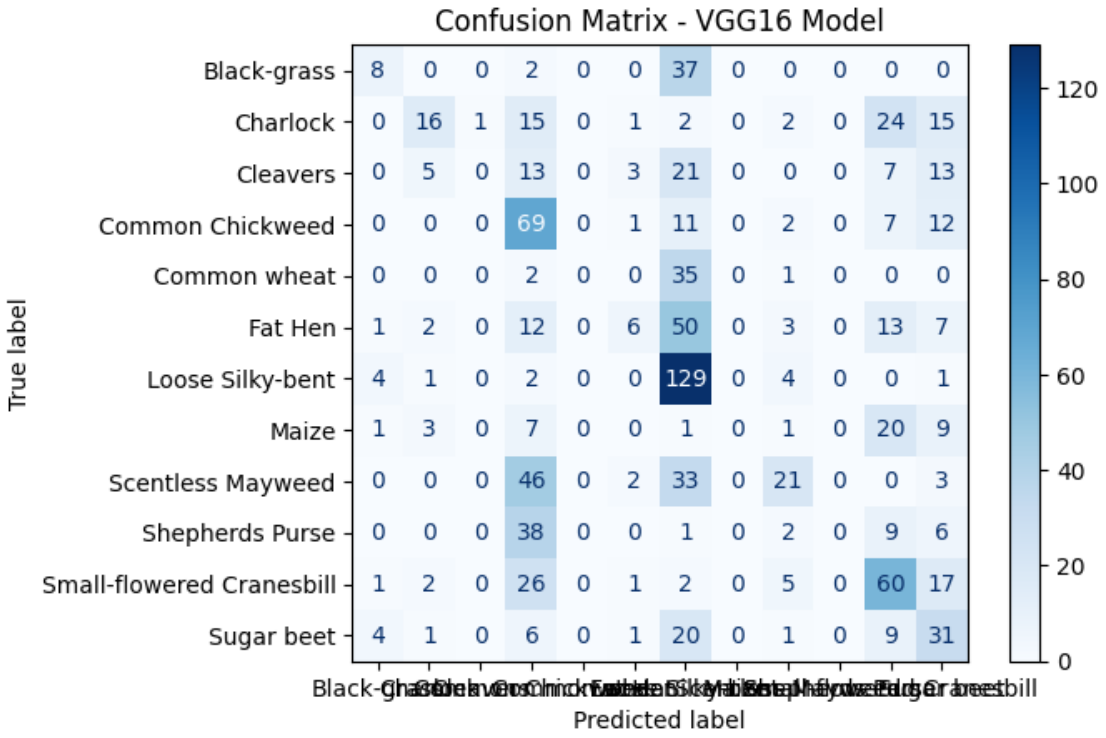
[34]:
```
# Plot accuracy and loss curves for VGG16
plt.figure(figsize=(12, 4))
plt.subplot(1, 2, 1)
plt.plot(history_vgg.history['accuracy'], label='VGG16 Train Accuracy')
plt.plot(history_vgg.history['val_accuracy'], label='VGG16 Validation Accuracy')
plt.title('VGG16 - Training and Validation Accuracy')
plt.xlabel('Epochs')
plt.ylabel('Accuracy')
plt.legend()

plt.subplot(1, 2, 2)
plt.plot(history_vgg.history['loss'], label='VGG16 Train Loss')
plt.plot(history_vgg.history['val_loss'], label='VGG16 Validation Loss')
plt.title('VGG16 - Training and Validation Loss')
plt.xlabel('Epochs')
plt.ylabel('Loss')
plt.legend()
plt.show()

# Plot accuracy and loss curves for ResNet50
plt.figure(figsize=(12, 4))
plt.subplot(1, 2, 1)
plt.plot(history_resnet.history['accuracy'], label='ResNet50 Train Accuracy')
plt.plot(history_resnet.history['val_accuracy'], label='ResNet50 Validation␣
 ↪Accuracy')
plt.title('ResNet50 - Training and Validation Accuracy')
plt.xlabel('Epochs')
plt.ylabel('Accuracy')
plt.legend()

plt.subplot(1, 2, 2)
plt.plot(history_resnet.history['loss'], label='ResNet50 Train Loss')
plt.plot(history_resnet.history['val_loss'], label='ResNet50 Validation Loss')
plt.title('ResNet50 - Training and Validation Loss')
plt.xlabel('Epochs')
plt.ylabel('Loss')
plt.legend()
plt.show()
```



5.5 5.5 Evaluate Models with Confusion Matrix and Classification Report

[35]:
```
# VGG16 model predictions
y_pred_vgg = np.argmax(vgg_model.predict(X_val), axis=1)

# Confusion matrix and classification report for VGG16
cm_vgg = confusion_matrix(y_val, y_pred_vgg)
disp_vgg = ConfusionMatrixDisplay(confusion_matrix=cm_vgg,␣
 ↪display_labels=label_encoder.classes_)
disp_vgg.plot(cmap=plt.cm.Blues)
plt.title('Confusion Matrix - VGG16 Model')
plt.show()
print(classification_report(y_val, y_pred_vgg, target_names=label_encoder.
 ↪classes_))
```

```
30/30              1s 31ms/step
```



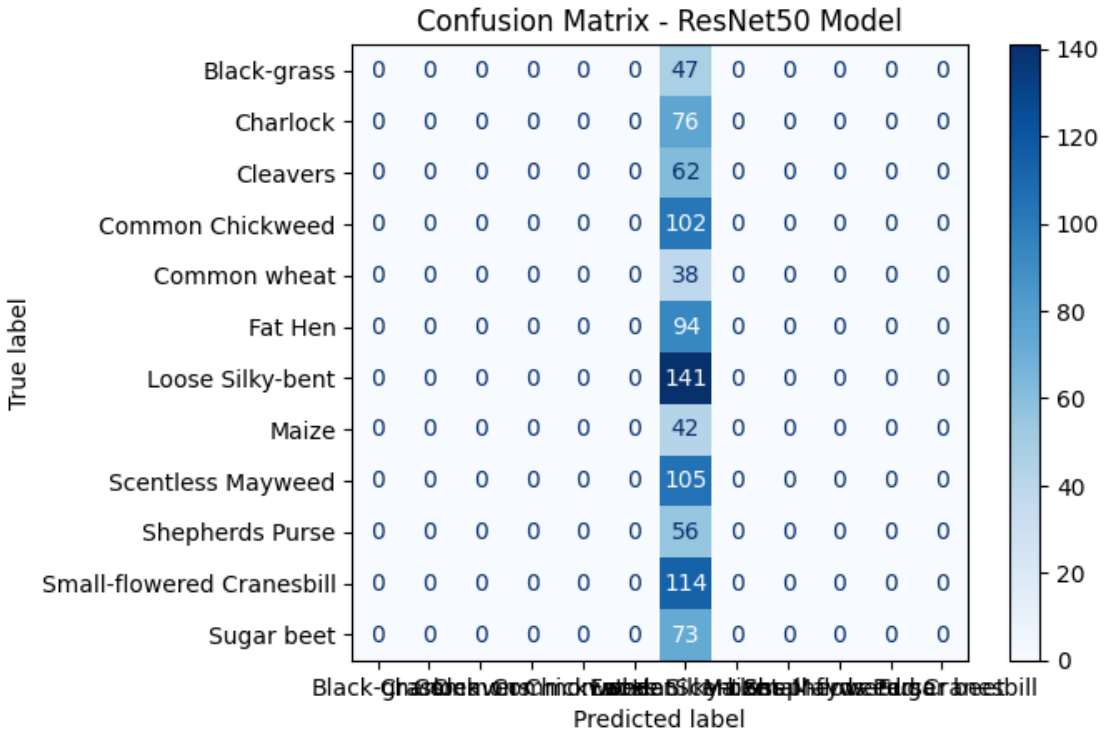
	precision	recall	f1-score	support
Black-grass	0.42	0.17	0.24	47
Charlock	0.53	0.21	0.30	76
Cleavers	0.00	0.00	0.00	62
Common Chickweed	0.29	0.68	0.41	102
Common wheat	0.00	0.00	0.00	38
Fat Hen	0.40	0.06	0.11	94
Loose Silky-bent	0.38	0.91	0.53	141
Maize	0.00	0.00	0.00	42
Scentless Mayweed	0.50	0.20	0.29	105
Shepherds Purse	0.00	0.00	0.00	56
Small-flowered Cranesbill	0.40	0.53	0.46	114
Sugar beet	0.27	0.42	0.33	73
accuracy			0.36	950
macro avg	0.27	0.27	0.22	950
weighted avg	0.31	0.36	0.28	950

```
/usr/local/lib/python3.10/dist-packages/sklearn/metrics/_classification.py:1531:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0 in labels
with no predicted samples. Use `zero_division` parameter to control this
behavior.
```

```
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
/usr/local/lib/python3.10/dist-packages/sklearn/metrics/_classification.py:1531:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0 in labels
with no predicted samples. Use `zero_division` parameter to control this
behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
/usr/local/lib/python3.10/dist-packages/sklearn/metrics/_classification.py:1531:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0 in labels
with no predicted samples. Use `zero_division` parameter to control this
behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
```

[36]:
```
# ResNet50 model predictions
y_pred_resnet = np.argmax(resnet_model.predict(X_val), axis=1)

# Confusion matrix and classification report for ResNet50
cm_resnet = confusion_matrix(y_val, y_pred_resnet)
disp_resnet = ConfusionMatrixDisplay(confusion_matrix=cm_resnet,␣
 ↪display_labels=label_encoder.classes_)
disp_resnet.plot(cmap=plt.cm.Blues)
plt.title('Confusion Matrix - ResNet50 Model')
plt.show()
print(classification_report(y_val, y_pred_resnet, target_names=label_encoder.
 ↪classes_))
```

```
30/30                7s 139ms/step
```

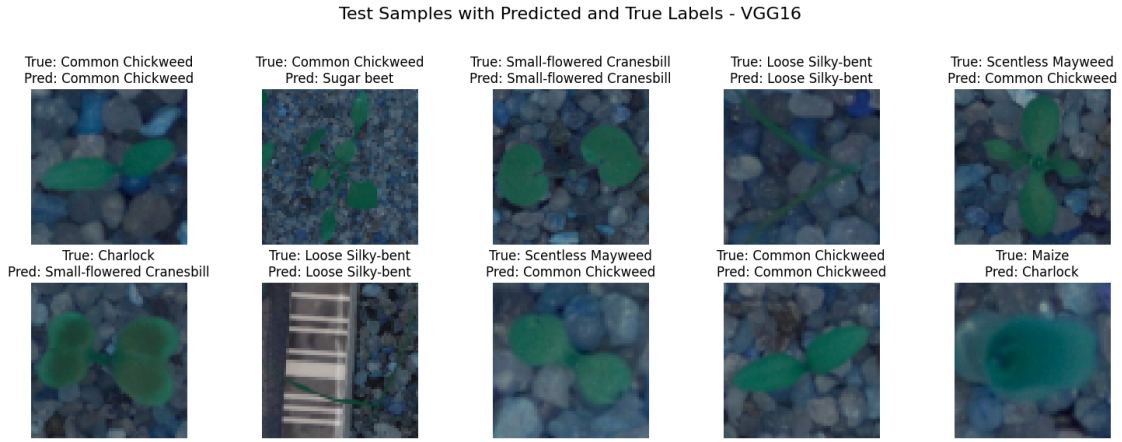


```
                           precision    recall  f1-score   support

              Black-grass       0.00      0.00      0.00        47
                 Charlock       0.00      0.00      0.00        76
                 Cleavers       0.00      0.00      0.00        62
         Common Chickweed       0.00      0.00      0.00       102
             Common wheat       0.00      0.00      0.00        38
                  Fat Hen       0.00      0.00      0.00        94
         Loose Silky-bent       0.15      1.00      0.26       141
                    Maize       0.00      0.00      0.00        42
        Scentless Mayweed       0.00      0.00      0.00       105
          Shepherds Purse       0.00      0.00      0.00        56
Small-flowered Cranesbill       0.00      0.00      0.00       114
               Sugar beet       0.00      0.00      0.00        73

                 accuracy                           0.15       950
                macro avg       0.01      0.08      0.02       950
             weighted avg       0.02      0.15      0.04       950

/usr/local/lib/python3.10/dist-packages/sklearn/metrics/_classification.py:1531:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0 in labels
with no predicted samples. Use `zero_division` parameter to control this
behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
/usr/local/lib/python3.10/dist-packages/sklearn/metrics/_classification.py:1531:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0 in labels
with no predicted samples. Use `zero_division` parameter to control this
behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
/usr/local/lib/python3.10/dist-packages/sklearn/metrics/_classification.py:1531:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0 in labels
with no predicted samples. Use `zero_division` parameter to control this
behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
```

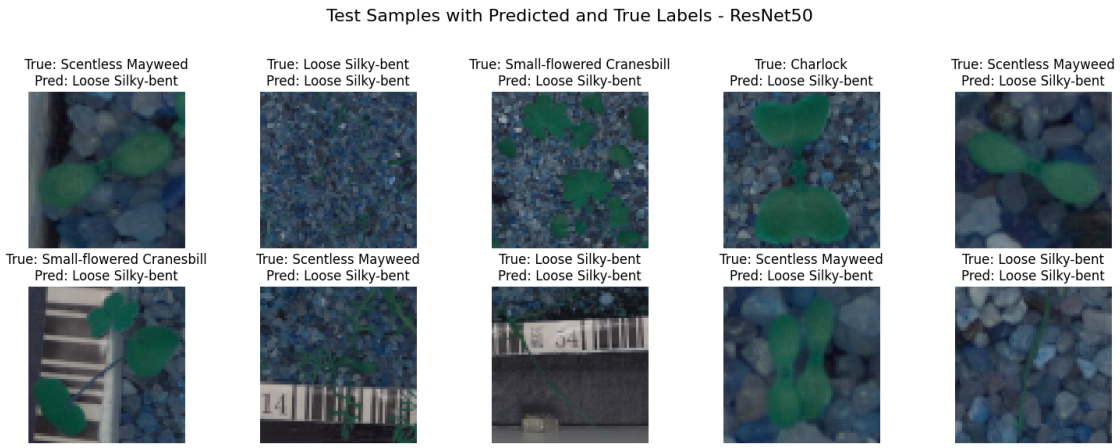
5.6 5.6 Visualize Test Samples with Predictions

[37]:
```python
# Visualize test samples with predictions for VGG16
fig, axes = plt.subplots(2, 5, figsize=(15, 6))
fig.suptitle('Test Samples with Predicted and True Labels - VGG16', fontsize=16)
sample_indices = random.sample(range(len(X_val)), 10)
for idx, ax in zip(sample_indices, axes.flat):
    ax.imshow(X_val[idx])
```

```
    ax.set_title(f"True: {label_encoder.
 ↪inverse_transform([y_val[idx]])[0]}\nPred: {label_encoder.
 ↪inverse_transform([y_pred_vgg[idx]])[0]}")
    ax.axis('off')
plt.tight_layout(rect=[0, 0.03, 1, 0.95])
plt.show()
```



[38]:
```
# Visualize test samples with predictions for ResNet50
import random

fig, axes = plt.subplots(2, 5, figsize=(15, 6))
fig.suptitle('Test Samples with Predicted and True Labels - ResNet50',␣
 ↪fontsize=16)

sample_indices = random.sample(range(len(X_val)), 10)
for idx, ax in zip(sample_indices, axes.flat):
    ax.imshow(X_val[idx])
    true_label = label_encoder.inverse_transform([y_val[idx]])[0]
    pred_label = label_encoder.inverse_transform([y_pred_resnet[idx]])[0]
    ax.set_title(f"True: {true_label}\nPred: {pred_label}")
    ax.axis('off')

plt.tight_layout(rect=[0, 0.03, 1, 0.95])
plt.show()
```



6 Step 6: Model Comparison and F1 Score Analysis

6.1 6.1 Calculate F1 Scores for Each Model

[39]:
```
from sklearn.metrics import f1_score

# Calculate F1 scores for each model
f1_basic_cnn = f1_score(y_val, y_pred, average='weighted')
f1_enhanced_cnn = f1_score(y_val, y_pred_enhanced, average='weighted')
f1_vgg16 = f1_score(y_val, y_pred_vgg, average='weighted')
f1_resnet50 = f1_score(y_val, y_pred_resnet, average='weighted')

# Display F1 scores
print(f"F1 Score - Basic CNN: {f1_basic_cnn:.4f}")
print(f"F1 Score - Enhanced CNN: {f1_enhanced_cnn:.4f}")
print(f"F1 Score - VGG16 Transfer Learning: {f1_vgg16:.4f}")
print(f"F1 Score - ResNet50 Transfer Learning: {f1_resnet50:.4f}")
```

```
F1 Score - Basic CNN: 0.7814
F1 Score - Enhanced CNN: 0.0047
F1 Score - VGG16 Transfer Learning: 0.2817
F1 Score - ResNet50 Transfer Learning: 0.0384
```

6.2 6.2 Store F1 Scores in a DataFrame

[40]:
```
# Create a DataFrame to store the F1 scores
f1_scores_df = pd.DataFrame({
    'Model': ['Basic_CNN', 'Enhanced_CNN', 'VGG16_Transfer_Learning',␣
 ↪'ResNet50_Transfer_Learning'],
    'F1 Score': [f1_basic_cnn, f1_enhanced_cnn, f1_vgg16, f1_resnet50]
})
```

```
# Display the DataFrame
print(f1_scores_df)
```

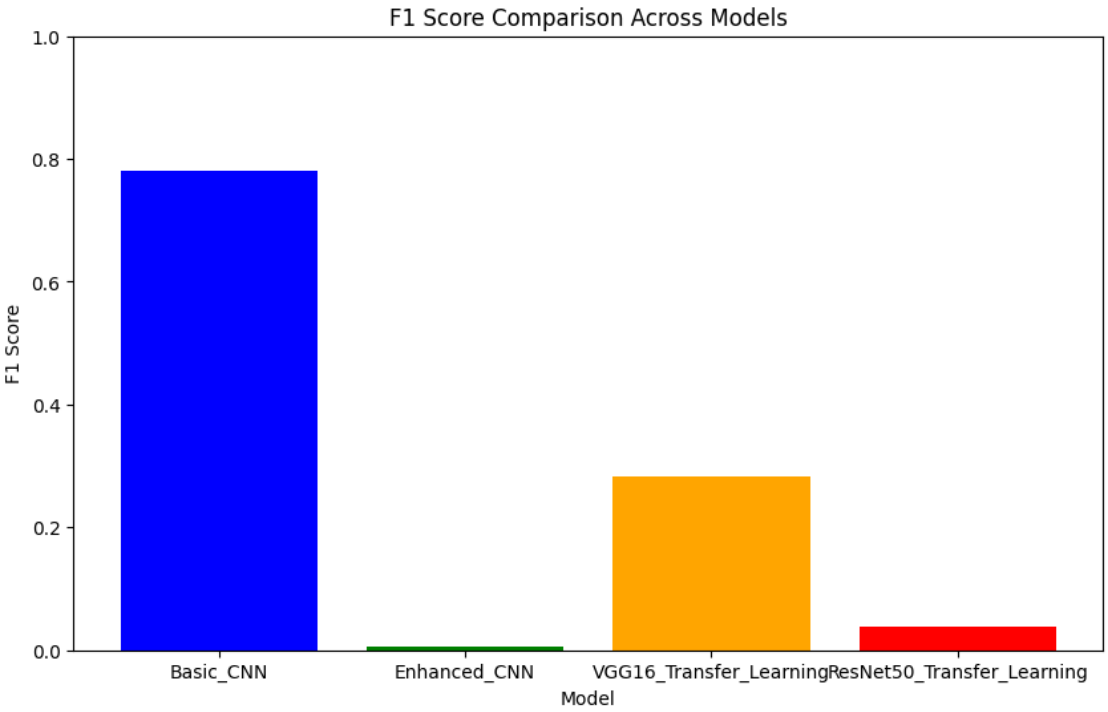
```
                        Model  F1 Score
0                  Basic_CNN  0.781416
1               Enhanced_CNN  0.004665
2    VGG16_Transfer_Learning  0.281706
3  ResNet50_Transfer_Learning  0.038364
```

6.3 Saving F1-Scores as CSV

[42]:
```
file_path = 'drive/My Drive/655_deep_learning/Assignmenet_2_f1_scores.csv'  #␣
 ↪Added a filename to the path
f1_scores_df.to_csv(file_path, index=False)
```

6.4 6.3 Visualize the F1 Score Comparison with a Bar Plot

[43]:
```
import matplotlib.pyplot as plt

# Plot the F1 score comparison
plt.figure(figsize=(10, 6))
plt.bar(f1_scores_df['Model'], f1_scores_df['F1 Score'], color=['blue',␣
 ↪'green', 'orange', 'red'])
plt.title('F1 Score Comparison Across Models')
plt.xlabel('Model')
plt.ylabel('F1 Score')
plt.ylim(0, 1)  # Set y-axis limits for better comparison
plt.show()
```


F1 Score Comparison Across Models
F1 Score
1.0
0.8
0.6
0.4
0.2
0.0
Basic_CNN
Enhanced_CNN
VGG16_Transfer_Learning
ResNet50_Transfer_Learning
Model