

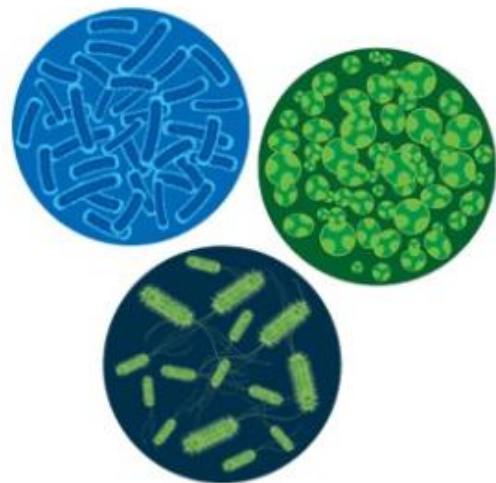
Project Report

Microbe Mapper: Visual Recognition Of Micro-Organisms

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1. INTRODUCTION.

1.1 Project Overview

In this project, we will be building a Deep learning model that can classify types of microorganisms. A web application is integrated with the model, from where the user can upload a sample microbe image and retrieve the class of the microorganisms.

1.2 Purpose

To accelerate Detection of microbe class with a sample image through deep learning methods.

2. LITERATURE SURVEY

Environmental Microorganisms (EMs), referring to microscopic life forms existing in nature and invisible to the naked eye, play a crucial role in human survival (Madigan et al., 1997; Rahaman et al., 2020). Some beneficial bacteria contribute to the production of fermented foods like cheese and bread, while others aid in plastic degradation, sulfur-containing waste gas treatment, and soil improvement. However, harmful EMs can lead to food spoilage, reduced crop production, and infectious disease epidemics. To leverage the advantages of EMs and mitigate their harmful effects, extensive research, particularly in EM image analysis, is underway.

Due to their small size (usually 0.1 to 100 microns), traditional morphological methods for EM detection involve manual microscopic observation, leading to increased labor and time costs (Madsen, 2008). Computer-assisted image analysis offers a more efficient alternative. Image analysis combines mathematical models and processing techniques to extract intelligence from images. Common processes include denoising, segmentation, and feature extraction. Denoising aims to recover the original image from noise, segmentation divides an image into regions of interest, and feature extraction retrieves important information for classification.

Traditional EM identification methods, such as chemical, physical, molecular biological, and morphological observation, have drawbacks like secondary pollution, expensive equipment, time requirements, and dependence on expert operators. Computer image analysis, encompassing computer vision and image processing, provides advantages over traditional methods, being indifferent to microbial species number, requiring less time, handling large datasets effortlessly, and being user-friendly.

Current research focuses on microorganism segmentation, clustering, classification, counting, and detection using computer-aided image analysis. While various literature reviews touch on microorganism-related topics, none comprehensively cover microorganism detection methods. Understanding these methods aids development in related fields like classification, segmentation, and retrieval.

Artificial Neural Networks (ANNs), inspired by biological neurons, have gained prominence in Microorganism Image Analysis (MIA). Early ANN development faced challenges, but with improved computer performance, Convolutional Neural Networks (CNNs) excelled in image recognition. ANNs are widely applied in MIA due to their ability to learn valuable patterns from extensive data.

Recent studies have utilized Machine Learning (ML) for automatic microscopic image recognition in microorganism classification. Literature reviews have covered Content-Based Microscopic Image Analysis (CBMIA) methods, image segmentation, and clustering methods applied in microorganism image analysis.

2.2 References

1. Maier R. M., Pepper I. L., Gerba C. P. *Environmental Microbiology*. Academic Press; 2009.
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3. Kosov S., Shirahama K., Li C., Grzegorzec M. Environmental microorganism classification using conditional random fields and deep convolutional neural networks. *Pattern Recognition*. 2018;77:248–261. doi: 10.1016/j.patcog.2017.12.021.
4. Li C., Wang K., Xu N. A survey for the applications of content-based microscopic image analysis in microorganism classification domains. *Artificial Intelligence Review*. 2019;51(4):577–646. doi: 10.1007/s10462-017-9572-4.
5. Yamaguchi T., Kawakami S., Hatamoto M., et al. In situ DNA-hybridization chain reaction (HCR): a facilitated in situ HCR system for the detection of environmental microorganisms. *Environmental Microbiology*. 2015;17(7):2532–2541. doi: 10.1111/1462-2920.12745.
6. Aydin AS, Dubey A, Dovrat D, Aharoni A, Shilkrot R. *Proceedings of the IEEE conference on computer vision and pattern recognition workshops*. Piscataway: IEEE; 2017. CNN based yeast cell segmentation in multi-modal fluorescent microscopy data; pp. 753–759
7. Baek SS, Pyo J, Pachepsky Y, Park Y, Ligaray M, Ahn CY, Kim YH, Chun JA, Cho KH. Identification and enumeration of cyanobacteria species using a deep neural network. *Ecol Indic*. 2020;115:106395. doi: 10.1016/j.ecolind.2020.106395.

2.3 Problem Statement Definition

Microorganisms such as protozoa and bacteria play very important roles in many practical domains, like agriculture, industry and medicine. To explore functions of different categories of microorganisms is a fundamental work in biological studies, which can assist biologists and related scientists to get to know more properties, habits and characteristics of these tiny but obligate living beings. However, taxonomy of microorganisms (microorganism classification) is traditionally investigated through morphological, chemical or physical analysis, which is time and money consuming. In order to overcome this, since the 1970s CBMIA methods are used to classify microorganisms into different categories using multiple artificial intelligence approaches, such as

machine vision, pattern recognition and machine learning algorithms. With the advancement of technology, many new techniques of Deep learning have contributed towards classification of image in a more efficient way such as ResNet, VGG16, Inception V3 etc. Here in the given project, we are using the Inception V3 to classify the microorganisms into their original classes

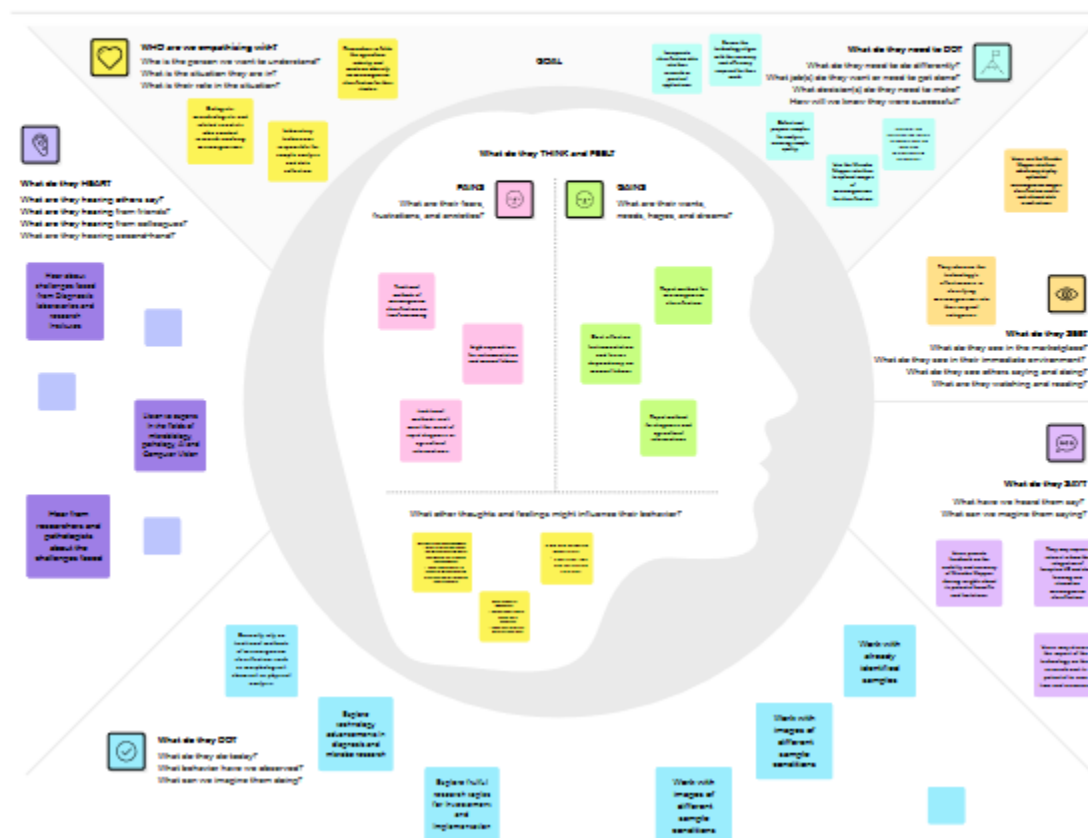
3. IDEATION & PROPOSED SOLUTION

3.1 Empathy Map Canvas

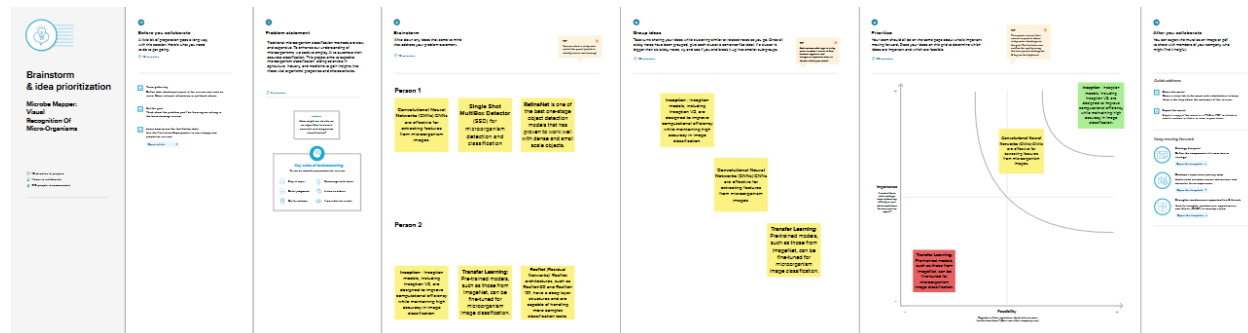


Microbe Mapper: Visual Recognition Of Micro-Organisms

The Microbe Mapper project intends to provide rapid, accurate, cost-effective solutions for visual identification of microorganisms using deep learning technology for applications in pathology and agriculture research.



3.2 Ideation & Brainstorming



4. REQUIREMENT ANALYSIS

4.1 Functional requirement

Pre-requisites:

To complete this project, you must require the following software's, concepts, and packages

Anaconda Navigator is a free and open-source distribution of the Python and R programming languages for data science and machine learning related applications. It can be installed on Windows, Linux, and macOS. Conda is an open-source, cross-platform, package management system. Anaconda comes with so very nice tools like JupyterLab, Jupyter Notebook, Spyder, Visual Studio Code. For this project, we will be using Jupyter notebook and Spyder

To install Anaconda navigator and to know how to use Jupyter Notebook & Spyder using Anaconda watch the video

Link: Click here to watch the video

1. To build Machine learning models you must require the following packages

- Numpy: o It is an open-source numerical Python library. It contains a multidimensional array and matrix data structures and can be used to perform mathematical operations
- Scikit-learn: o It is a free machine learning library for Python. It features various algorithms like support vector machine, random forests, and k-neighbours, and it also supports Python numerical and scientific libraries like NumPy and SciPy
- Flask: Web framework used for building Web applications Python packages:
 - open anaconda prompt as administrator
 - Type "pip install numpy" and click enter.
 - Type "pip install pandas" and click enter.
 - Type "pip install scikit-learn" and click enter.

- Type “pip install tensorflow==2.3.2” and click enter.
- Type “pip install keras==2.3.1” and click enter. ✓ Type “pip install Flask” and click enter.

Deep Learning Concepts

CNN: a convolutional neural network is a class of deep neural networks, most commonly applied to analysing visual imagery.

CNN Basic

Flask: Flask is a popular Python web framework, meaning it is a third-party Python library used for developing web applications.

Flask Basics

If you are using Pycharm IDE, you can install the packages through the command prompt and follow the same syntax as above.

Project Objectives:

By the end of this project, you will:

Know fundamental concepts and techniques of Convolutional Neural Network.

Gain a broad understanding of image data.

Know how to pre-process/clean the data using different data pre-processing techniques. know how to build a web application using the Flask framework.

Project Flow:

- The user interacts with the UI (User Interface) to choose the image.
- The chosen image analysed by the model which is integrated with flask application.
- Inceptionv3 Model analyse the image, then prediction is showcased on the Flask UI.

To accomplish this, we have to complete all the activities and tasks listed below

Data Collection.

- Create Train and Test Folders.

Data Pre-processing.

- Import the ImageDataGenerator library
- Configure ImageDataGenerator class
- Apply ImageDataGenerator functionality to Trainset and Test set

Model Building

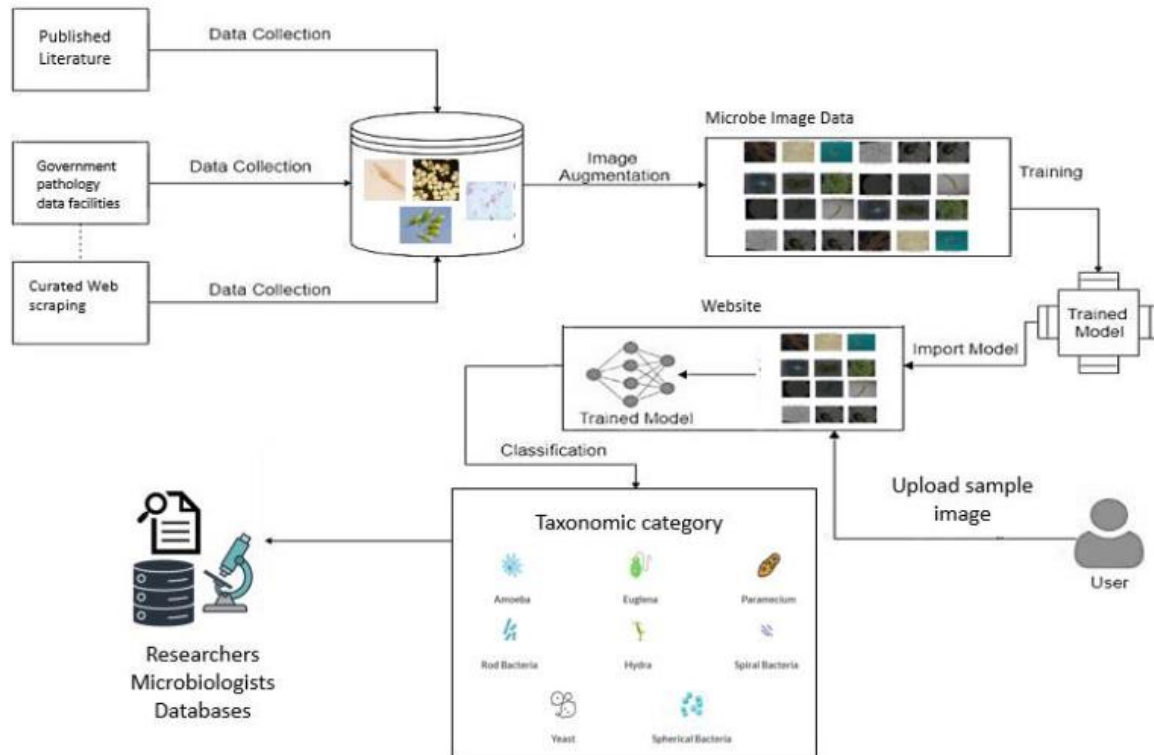
- Import the model building Libraries
- Initializing the model
- Adding Input Layer
- Adding Hidden Layer
- Adding Output Layer
- Configure the Learning Process

Training and testing the model

- Save the Model
- Application Building
- Create an HTML file
- Build Python Code

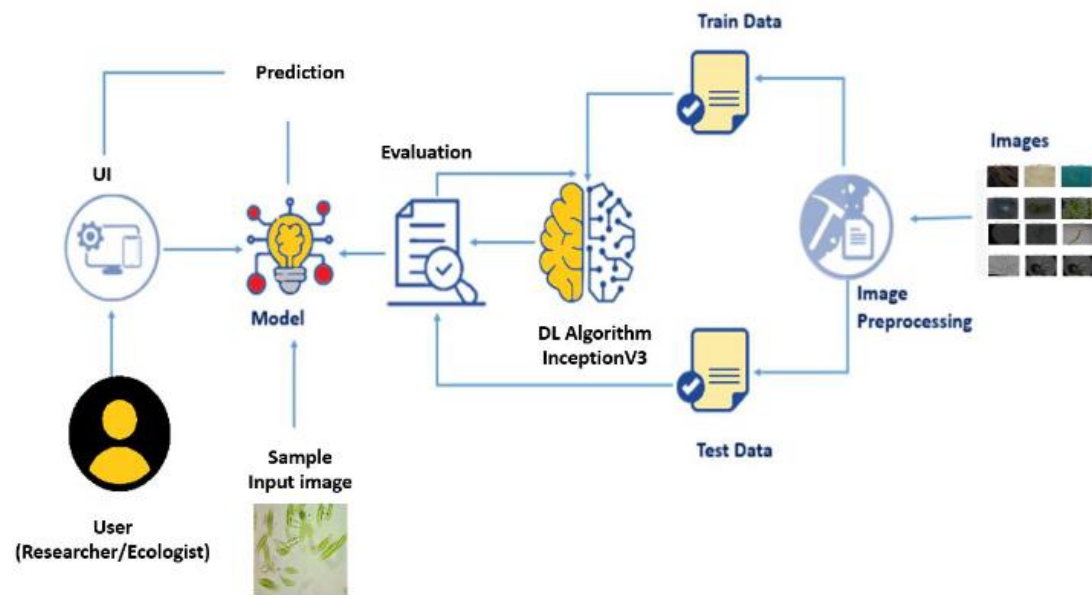
5. PROJECT DESIGN

5.1 Data Flow Diagrams & User Stories



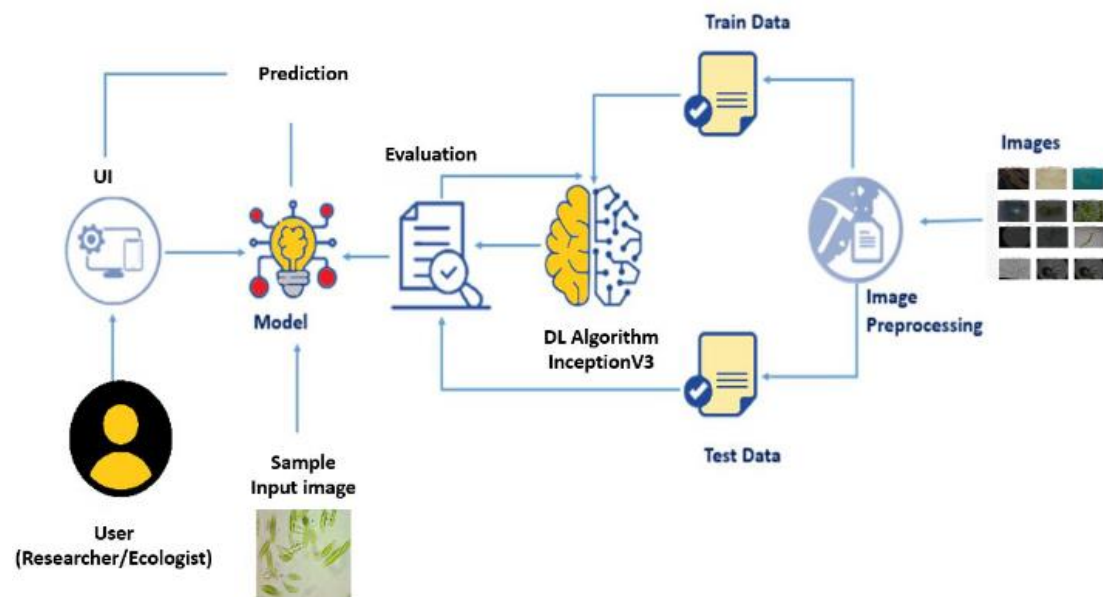
User Type	Functional Requirement (Epic)	User Story Number	User Story / Task	Acceptance criteria	Priority	Release
Hospitals & microbiology laboratories	Project setup &	USN-1	Set up the tools and frameworks to start the AI based pathology	successfully configured with all necessary tools and frameworks	High	Sprint 1
	Infrastructure					
Governments laboratories	development environment	USN-2	Gather a diverse dataset of images containing different types of microbes for training the deep learning model.	Gathered a diverse dataset of images	High	Sprint 1
Bioinformatics Centers, Automation tools	Data collection	USN-3	Preprocess the collected dataset by resizing images, normalizing pixel values, and splitting it into training and validation sets.	preprocessed the dataset	High	Sprint 2
Researchers and Academia	data preprocessing	USN-4	Explore and evaluate different deep learning architectures to select the most suitable model for microbe classification	we could explore various DL models	High	Sprint 2
Bioinformatics and ML team	model development	USN-5	train the selected deep learning model using the preprocessed dataset and monitor its performance on the validation set.	we could do validation	High	Sprint 3
3rd party company and industry players	model deployment &	USN-7	deploy the trained deep learning model as an API or web service to	we could check the scalability	medium	Sprint 4
	Integration		make it accessible for microbe classification. integrate the model's API into a user-friendly web interface for users to upload images and receive microbe classification results.			
Government regulatory body	Testing & quality assurance	USN-8	conduct thorough testing of the model and web interface to	we could create web application	medium	Sprint 5
			identify and report any issues or bugs. fine-tune the model hyperparameters and optimize its performance based on user feedback and testing results.			

5.2 Solution Architecture



6. PROJECT PLANNING & SCHEDULING

6.1 Technical Architecture



6.2 Sprint Planning & Estimation

Sprint	Functional Requirement (Epic)	User Story Number	User Story / Task	Story Points	Priority	Team Members
Sprint-1	Project setup & Infrastructure	USN-1	Set up the development environment with the required tools and frameworks to start the microbe classification	1	High	
Sprint-1	development environment	USN-2	Gather a diverse dataset of images containing different types of microbes	2	High	
Sprint-2	Data collection	USN-3	Preprocess the collected dataset by resizing images, normalizing pixel values, and splitting it into training and validation sets.	2	High	
Sprint-2	data preprocessing	USN-4	Explore and evaluate different deep learning architectures (e.g., CNNs) to select the most suitable model for microbe classification.	3	High	
Sprint-3	model development	USN-5	train the selected deep learning model using the preprocessed dataset and monitor its performance on the validation set.	4	High	
Sprint-3	Training	USN-6	implement data augmentation techniques like resizing to improve the model's robustness and accuracy.	6	medium	
Sprint-4	model deployment & Integration	USN-7	deploy the trained deep learning model as a web service to make it accessible for microbe classification for users to upload images and get results	1	medium	
Sprint-5	Testing & quality assurance	USN-8	conduct thorough testing of the model and web interface to identify and report any issues or bugs. fine-tune the model hyperparameters and optimize its performance based on user feedback and testing results.	1	medium	

6.3 Sprint Delivery Schedule

Sprint	Total Story Points	Duration	Sprint Start Date	Sprint End Date (Planned)	Story Points Completed (as on Planned End Date)	Sprint Release Date (Actual)
Sprint-1	3	3 Days	24 Oct 2022	29 Oct 2022	20	20 Nov 2023
Sprint-2	5	5 Days	31 Oct 2022	05 Nov 2022		
Sprint-3	10	7 Days	07 Nov 2022	12 Nov 2022		
Sprint-4	1	7 Days	14 Nov 2022	19 Nov 2022		
Sprint-5	1	7 Days	19 Nov 2023	20 Nov 2023		

7. CODING & SOLUTIONING

(Explain the features added in the project along with code)

Milestone 1: Collection of Data

Data Collection Collect images of micro-organisms then organized into subdirectories based on their respective names as shown in the project structure. Create folders of types of microbes that need to be recognized.

The given dataset has 8 different types of folders given for Micro Organism they are following:

- Amoeba
- Euglena

- Hydra
- Paramecium
- Rod bacteria
- Spherical bacteria
- Spiral bacteria
- Yeast

Download the Dataset-

<https://www.kaggle.com/datasets/mdwaquarazam/microorganism-image-classification>

Milestone 2: Image Pre-processing

In this milestone we will be improving the image data that suppresses unwilling distortions or enhances some image features important for further processing, although perform some geometric transformations of images like rotation, scaling, translation, etc.

Activity 1: Import the ImageDataGenerator library

Image data augmentation is a technique that can be used to artificially expand the size of a training dataset by creating modified versions of images in the dataset. The Keras deep learning neural network library provides the capability to fit models using image data augmentation via the ImageDataGenerator class. Let us import the

ImageDataGenerator class from TensorFlow Keras

```
# making all necessary imports

import os
import keras
import numpy as np
import pandas as pd
import seaborn as sns
import tensorflow as tf
from keras.preprocessing.image import ImageDataGenerator
import plotly.express as px
import matplotlib.pyplot as plt
from keras.models import Sequential, load_model
from keras.layers import GlobalAvgPool2D as GAP, Dense, Dropout
from keras.callbacks import EarlyStopping as ES, ModelCheckpoint as MC
from tensorflow.keras.applications import ResNet50V2, ResNet50, InceptionV3, Xception
from matplotlib import RcParams
import warnings
warnings.filterwarnings('ignore')
```

Activity 2: Configure ImageDataGenerator class

ImageDataGenerator class is instantiated and the configuration for the types of data augmentation

```
gen = ImageDataGenerator(rescale=1./255, rotation_range=10, horizontal_flip=True, brightness_range=[0.3,0.8], validation_s
```

There are five main types of data augmentation techniques for image data; specifically:

Image shifts via the width_shift_range and height_shift_range arguments.

The image flips via the horizontal flip and vertical flip arguments. Image rotations via the rotation range argument Image brightness via the brightness range argument.

Image zoom via the zoom range argument. An instance of the

ImageDataGenerator class can be constructed for train and test.

Activity 3: Apply ImageDataGenerator functionality to Trainset and Test set

Let us apply ImageDataGenerator functionality to Trainset and Test set by using the following code. For Training set using flow_from_directory function.

This function will return batches of images from the different classes as 'Amoeba': 0,

'Euglena': 1, 'Hydra': 2, 'Paramecium': 3, 'Rod_bacteria': 4, 'Spherical_bacteria': 5, 'Spiral_bacteria': 6, 'Yeast': 7

Arguments:

directory: Directory where the data is located. If labels are "inferred", it should contain subdirectories, each containing images for a class. Otherwise, the directory structure is ignored. batch_size: Size of the batches of data which is 64. target_size: Size to resize images after they are read from disk. class_mode:

- 'int': means that the labels are encoded as integers (e.g., for sparse_categorical_crossentropy loss).
- 'categorical' means that the labels are encoded as a categorical vector (e.g., for categorical_crossentropy loss).
- 'binary' means that the labels (there can be only 2) are encoded as float32 scalars with values 0 or 1 (e.g., for binary_crossentropy).
- None (no labels).

```

: train_ds= gen.flow_from_directory(
    '/content/Micro_Organism/',
    batch_size=128,
    shuffle=True,
    class_mode='binary',
    target_size=(256,256),
    subset='training'
)
valid_ds= gen.flow_from_directory(
    '/content/Micro_Organism/',
    batch_size=64,
    shuffle=True,
    class_mode='binary',
    target_size=(256,256),
    subset='validation'
)

```

Found 714 images belonging to 8 classes.
Found 75 images belonging to 8 classes.

Milestone 3: Model Building

Now it's time to build our Convolutional Neural Networking which contains an input layer along with the convolution, max-pooling, and finally an output layer.

Activity 1: Importing the Model Building Libraries

Importing the necessary libraries

```

# making all necessary imports

import os
import keras
import numpy as np
import pandas as pd
import seaborn as sns
import tensorflow as tf
from keras.preprocessing.image import ImageDataGenerator
import plotly.express as px
import matplotlib.pyplot as plt
from keras.models import Sequential, load_model
from keras.layers import GlobalAvgPool2D as GAP, Dense, Dropout
from keras.callbacks import EarlyStopping as ES, ModelCheckpoint as MC
from tensorflow.keras.applications import ResNet50V2, ResNet50, InceptionV3, Xception
from matplotlib import RcParams
import warnings
warnings.filterwarnings('ignore')

```

Activity 2: Exploratory Data Analysis

```
class_names = sorted(os.listdir('/content/Micro_Organism/'))
n_classes = len(class_names)
print('class_names: ',class_names)
print('number_of_classes: ',n_classes)
```

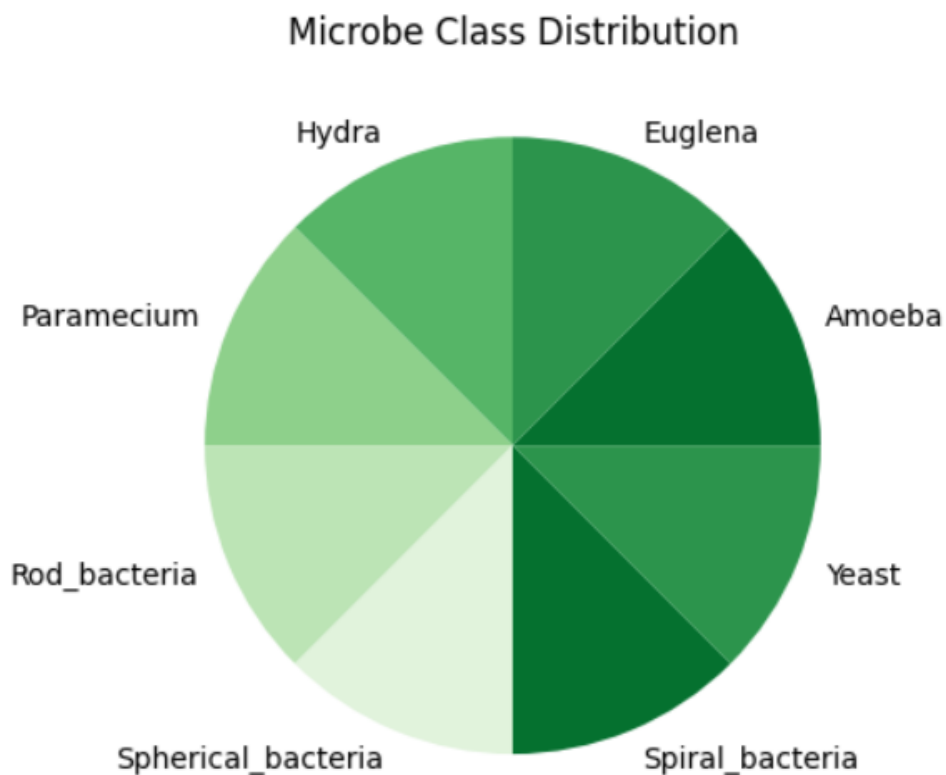
```
class_names: ['Amoeba', 'Euglena', 'Hydra', 'Paramecium', 'Rod_bacteria', 'Spherical_bacteria', 'Spiral_bacteria', 'Yeast']
number_of_classes: 8
```

```
# fig = px.pie(names=class_names, title="Class Distribution")
# fig.update_layout({'title':{'x':0.45}})
# fig.show()
```

Activity 3: Visualisation of the data

```
# fig = px.pie(names=class_names, title="Class Distribution")
# fig.update_layout({'title':{'x':0.45}})
# fig.show()

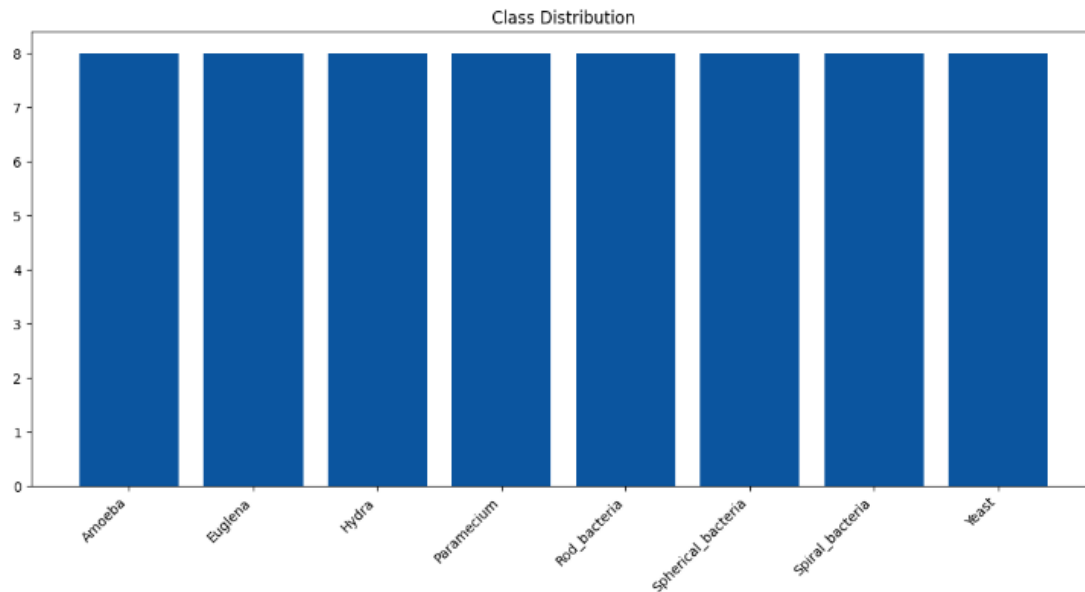
# plt.pie(names=class_names, labels=class_names)
# plt.title("Class Distribution", loc="center", pad=20)
# plt.show()
sns.set_palette('Greens_r')
plt.pie([1] * len(class_names), labels=class_names)
plt.title("Microbe Class Distribution", loc="center")
plt.show()
```



```

sns.set_palette('Blues_r')
plt.figure(figsize=(14, 6))
plt.bar(class_names, n_classes)
plt.title("Class Distribution")
plt.xticks(rotation=45, ha='right')
# Show the plot
plt.show()

```



```

def show_images(data, GRID=[2,6], model=None, size=(25,10)):

    # The plotting configurations
    n_rows, n_cols = GRID
    n_images = n_rows * n_cols
    plt.figure(figsize=size)

    # Data for visualization
    images, labels = next(iter(data)) # This process can take a little time because of the large batch size

    # Iterate through the subplots.
    for i in range(1, n_images+1):

        # Select a random data
        id = np.random.randint(len(images)) # This is a dynamic function because for validation data and training data, the
        image, label = images[id], class_names[int(labels[id])]

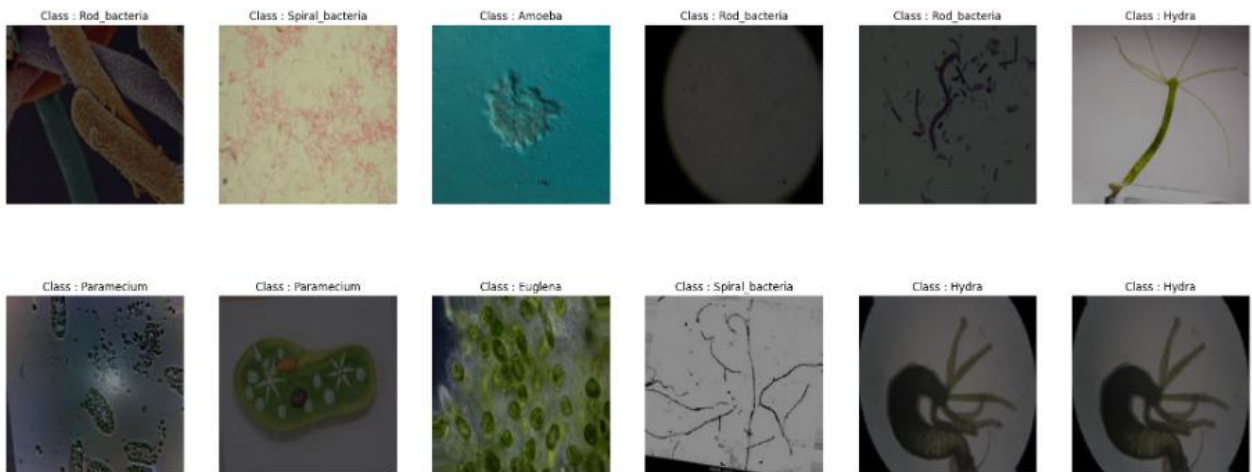
        # Plot the sub plot
        plt.subplot(n_rows, n_cols, i)
        plt.imshow(image)
        plt.axis('off')
        # If model is available make predictions.
        if model is not None:
            pred = class_names[np.argmax(model.predict(image[np.newaxis,...]))]
            title = f"Class : {label}\nPred : {pred}"
        else:
            title = f"Class : {label}"

        plt.title(title)
    plt.show()

```



```
In [14]: show_images(data=train_ds)
```



Activity 4: Initializing the model

Keras has 2 ways to define a neural network:

Sequential

Function API

The Sequential class is used to define linear initializations of network layers which then, collectively, constitute a model. In our example below, we will use the Sequential constructor to create a model, which will then have layers added to it using the add() method.

Activity 5: Configure the Learning Process

The compilation is the final step in creating a model. Once the compilation is done, we can move on to the training phase. The loss function is used to find errors or deviations in the learning process. Keras requires a loss function during the model compilation process.

Optimization is an important process that optimizes the input weights by comparing the prediction and the loss function. Here we are using adam optimizer

Metrics are used to evaluate the performance of your model. It is similar to the loss function, but not used in the training process

Activity 6: Train The model

Now, let us train our model with our image dataset. The model is trained for 30 epochs and after every epoch, the current model state is saved if the model has the least loss encountered till that time. We can see that the training loss decreases in almost every epoch till 30 epochs and probably there is further scope to improve the model. fit_generator functions used to train a deep learning neural network

Arguments:

steps_per_epoch: it specifies the total number of steps taken from the generator as soon as one epoch is finished and the next epoch has started. We can calculate the value of **steps_per_epoch** as the total number of samples in your dataset divided by the batch size.

Epochs: an integer and number of epochs we want to train our model for.

validation_data can be either:

- an inputs and targets list
- a generator
- an inputs, targets, and sample_weights list which can be used to evaluate the loss and metrics for any model after any epoch has ended.
- **validation_steps:** only if the **validation_data** is a generator then only this argument can be used. It specifies the total number of steps taken from the generator before it is stopped at every epoch and its value is calculated as the total number of validation data points in your dataset divided by the validation batch size

```
# Give you a model, a name
name = "inception-v3"

# Base model
base = InceptionV3(input_shape=(256,256,3), include_top=False)
base.trainable = False

# Model Architecture
model = Sequential([
    base, GAP(),
    Dense(256, kernel_initializer='he_normal', activation='relu'),
    Dropout(0.2),
    Dense(n_classes, activation='softmax')
])

# Callbacks
cbs = [ES(patience=3, restore_best_weights=True), MC(name + ".h5", save_best_only=True)]

# Compile Model
opt = tf.keras.optimizers.Adam(learning_rate=1e-3) # Higher than the default learning rate 1e-3
model.compile(loss='sparse_categorical_crossentropy', optimizer=opt, metrics=['accuracy'])

# Training
history = model.fit(train_ds, validation_data=valid_ds, epochs=50, callbacks=cbs)
```

Analysing the trained model by looking at the accuracy through the epochs:

```

Downloading data from https://storage.googleapis.com/tensorflow/keras-applications/inception_v3/inception_v3_weights_tf_dim_ordering_tf_kernels_notop.h5
87910968/87910968 [=====] - 1s 0us/step
Epoch 1/50
6/6 [=====] - 43s 4s/step - loss: 2.3698 - accuracy: 0.2101 - val_loss: 1.6713 - val_accuracy: 0.3867
Epoch 2/50
6/6 [=====] - 25s 4s/step - loss: 1.6406 - accuracy: 0.4272 - val_loss: 1.3934 - val_accuracy: 0.5067
Epoch 3/50
6/6 [=====] - 22s 3s/step - loss: 1.2546 - accuracy: 0.5952 - val_loss: 1.2651 - val_accuracy: 0.6267
Epoch 4/50
6/6 [=====] - 21s 3s/step - loss: 1.0707 - accuracy: 0.6625 - val_loss: 1.0814 - val_accuracy: 0.6133
Epoch 5/50
6/6 [=====] - 18s 3s/step - loss: 0.9312 - accuracy: 0.6863 - val_loss: 1.1289 - val_accuracy: 0.6000
Epoch 6/50
6/6 [=====] - 22s 4s/step - loss: 0.8170 - accuracy: 0.7269 - val_loss: 1.0833 - val_accuracy: 0.6400
Epoch 7/50
6/6 [=====] - 20s 3s/step - loss: 0.7743 - accuracy: 0.7479 - val_loss: 1.0415 - val_accuracy: 0.6533
Epoch 8/50
6/6 [=====] - 21s 4s/step - loss: 0.6723 - accuracy: 0.7843 - val_loss: 1.0062 - val_accuracy: 0.7067
Epoch 9/50
6/6 [=====] - 22s 4s/step - loss: 0.6172 - accuracy: 0.7983 - val_loss: 1.0328 - val_accuracy: 0.6800
Epoch 10/50
6/6 [=====] - 18s 3s/step - loss: 0.5701 - accuracy: 0.8179 - val_loss: 1.0517 - val_accuracy: 0.6400
Epoch 11/50
6/6 [=====] - 19s 3s/step - loss: 0.4999 - accuracy: 0.8473 - val_loss: 1.0725 - val_accuracy: 0.6667

```

Visualising Model Summary:

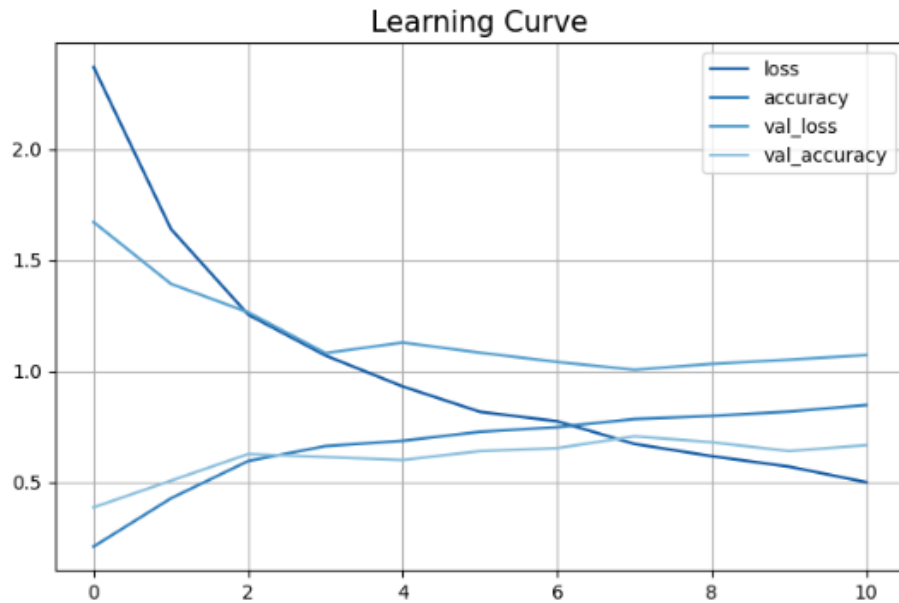
```
model.summary()
```

Model: "inception_v3"

Layer (type)	Output Shape	Param #	Connected to
input_2 (InputLayer)	[(None, 299, 299, 3)]	0	[]
conv2d_94 (Conv2D)	(None, 149, 149, 32)	864	['input_2[0][0]']
batch_normalization_94 (Batch Normalization)	(None, 149, 149, 32)	96	['conv2d_94[0][0]']
activation_94 (Activation)	(None, 149, 149, 32)	0	['batch_normalization_94[0][0]']
conv2d_95 (Conv2D)	(None, 147, 147, 32)	9216	['activation_94[0][0]']
batch_normalization_95 (Batch Normalization)	(None, 147, 147, 32)	96	['conv2d_95[0][0]']
avg_pool (GlobalAveragePooling2D)	(None, 2048)	0	['mixed10[0][0]']
predictions (Dense)	(None, 1000)	2049000	['avg_pool[0][0]']
Total params: 23851784 (90.99 MB)			
Trainable params: 23817352 (90.86 MB)			
Non-trainable params: 34432 (134.50 KB)			

Visualising the loss and accuracy of the trained model.

```
pd.DataFrame(history.history).plot(figsize=(8,5))
plt.title("Learning Curve", fontsize=15)
plt.grid()
plt.show()
```



Activity 7: Save the Model

The model is saved with .h5 extension as follows An H5 file is a data file saved in the Hierarchical Data Format (HDF). It contains multidimensional arrays of scientific data.

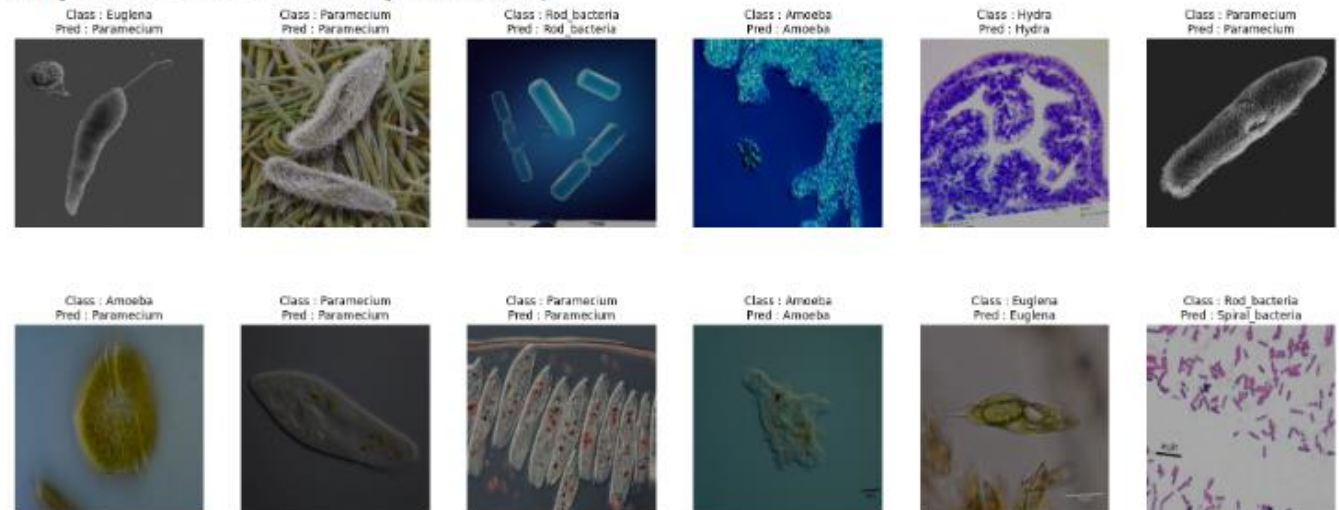
```
model.save('microbeclassification.h5')
```

Activity 8: Test The model

Evaluation is a process during the development of the model to check whether the model is the best fit for the given problem and corresponding data. Load the saved model using load_model

```
show_images(data=valid_ds, model=model)
```

```
1/1 [=====] - 2s 2s/step
1/1 [=====] - 0s 27ms/step
1/1 [=====] - 0s 24ms/step
1/1 [=====] - 0s 26ms/step
1/1 [=====] - 0s 28ms/step
1/1 [=====] - 0s 23ms/step
1/1 [=====] - 0s 24ms/step
1/1 [=====] - 0s 25ms/step
1/1 [=====] - 0s 24ms/step
1/1 [=====] - 0s 24ms/step
1/1 [=====] - 0s 24ms/step
1/1 [=====] - 0s 25ms/step
```



Taking an image as input and checking the results. Displaying 4 Test Results.

For the sake of testing multiple images, an additional function was written.

```
import numpy as np
import matplotlib.pyplot as plt
from tensorflow.keras.preprocessing import image

def predict(img_path, model):
    img = image.load_img(img_path, target_size=(256, 256))
    x = image.img_to_array(img)
    x = np.expand_dims(x, axis=0)
    x /= 255.0 # Normalize the pixel values

    predictions = model.predict(x)

    # Decode the predictions
    class_names = ['Amoeba', 'Euglena', 'Hydra', 'Paramecium', 'Rod_bacteria', 'Spherical_bacteria', 'Spiral_bacteria', 'Yeast']
    predicted_class = class_names[np.argmax(predictions)]

    # Display the image and predicted class
    plt.imshow(img)
    plt.title(f'Predicted Class: {predicted_class}')
    plt.axis('off')

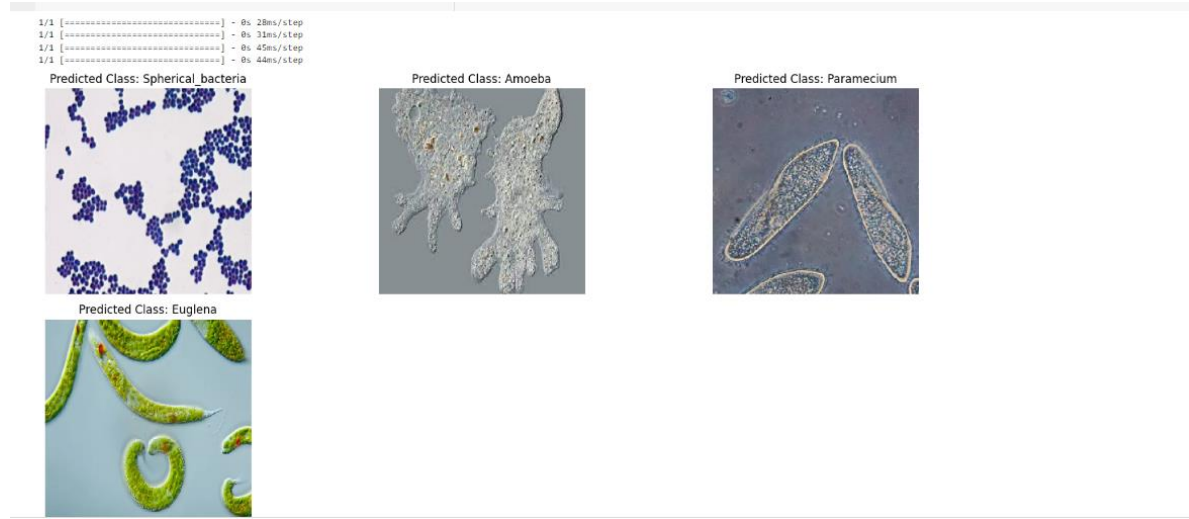
def show_images_in_subplot(paths, model, cols=3, rows=None):
    if rows is None:
        rows = len(paths) // cols + (len(paths) % cols > 0) # Calculate the number of rows dynamically

    plt.figure(figsize=(15, 7))

    for i, img_path in enumerate(paths, 1):
        plt.subplot(rows, cols, i)
        predict(img_path, model)

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

paths = ['/content/spherical.jpg', '/content/amoeba.jpg', '/content/paramecium.jpg', '/content/Euglena.jpg']
show_images_in_subplot(paths, model)
```



Milestone 4: Application Building

Now that we have trained our model, let us build our flask application which will be running in our local browser with a user interface.

In the flask application, the input parameters are taken from the HTML page. These factors are then given to the model to know to predict the type of Garbage and showcased on the HTML page to notify the user. Whenever the user interacts with the UI and selects the “Image” button, the next page is opened where the user chooses the image and predicts the output.

Activity 1: Create HTML Pages

- We use HTML to create the front end part of the web page.
- Here, we have created 2 HTML pages- index.html, prediction.html,
- Intro.html displays an introduction about the project
- We also use JavaScript-main.js and CSS-main.css to enhance our functionality and view of HTML pages.

```

Debug mode: OFF
WARNING: This is a development server. Do not use it in a production deployment. Use a production WSGI server instead.
* Running on http://127.0.0.1:5000
Press CTRL+C to quit
127.0.0.1 - - [21/Nov/2023 11:37:39] "GET / HTTP/1.1" 200 -
127.0.0.1 - - [21/Nov/2023 11:37:39] "GET /static/style.css HTTP/1.1" 304 -
127.0.0.1 - - [21/Nov/2023 11:37:39] "GET /static/img/picture2.png HTTP/1.1" 304 -
127.0.0.1 - - [21/Nov/2023 11:37:39] "GET /static/img/first.png HTTP/1.1" 304 -
127.0.0.1 - - [21/Nov/2023 11:37:39] "GET /static/img/second.png HTTP/1.1" 304 -
127.0.0.1 - - [21/Nov/2023 11:37:39] "GET /static/img/third.png HTTP/1.1" 304 -
127.0.0.1 - - [21/Nov/2023 11:37:40] "GET /favicon.ico HTTP/1.1" 404 -
127.0.0.1 - - [21/Nov/2023 11:37:43] "GET /prediction.html HTTP/1.1" 200 -
127.0.0.1 - - [21/Nov/2023 11:37:43] "GET /static/style.css HTTP/1.1" 304 -
127.0.0.1 - - [21/Nov/2023 11:37:43] "GET /static/img/testimonials/stages.png HTTP/1.1" 404 -
127.0.0.1 - - [21/Nov/2023 11:37:43] "GET /static/img/dummy/dr.jpg HTTP/1.1" 304 -

```

Create app.py (Python Flask) file: -

The image shows two screenshots of a VS Code editor. The top screenshot shows the initial setup of the app.py file, and the bottom screenshot shows the completed code.

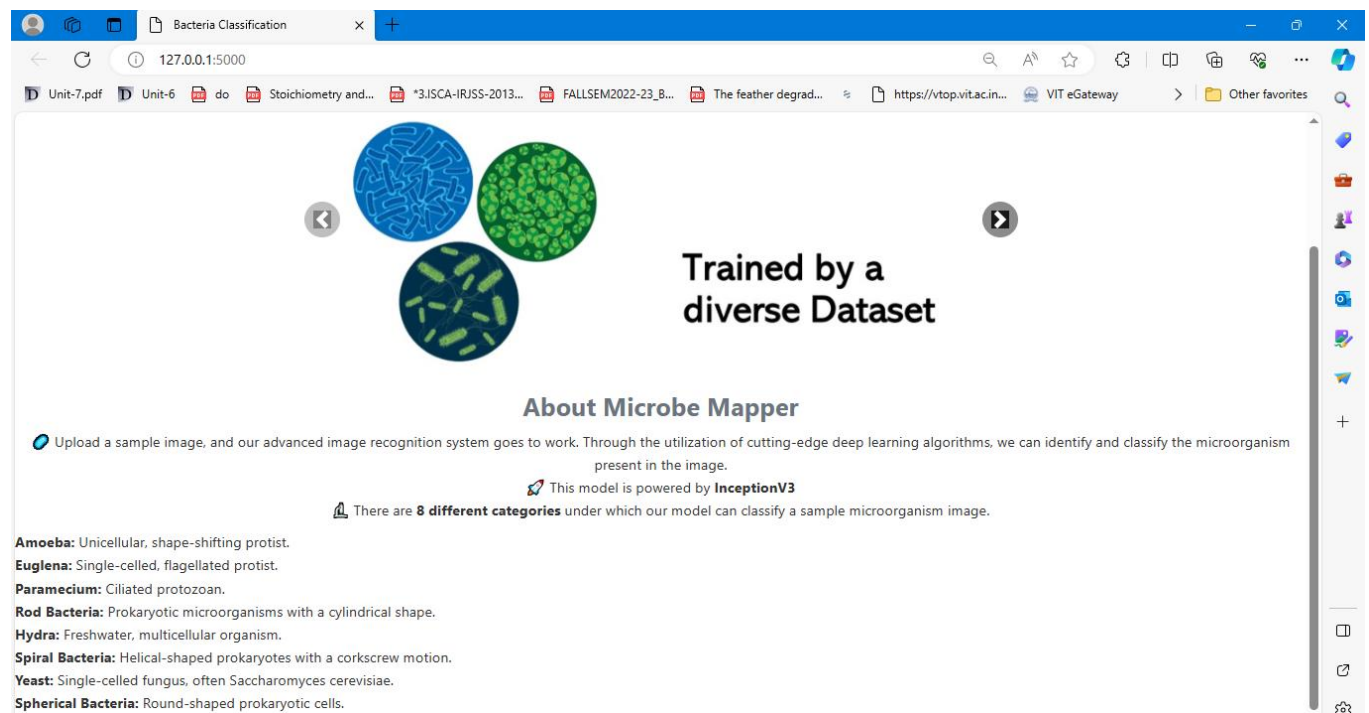
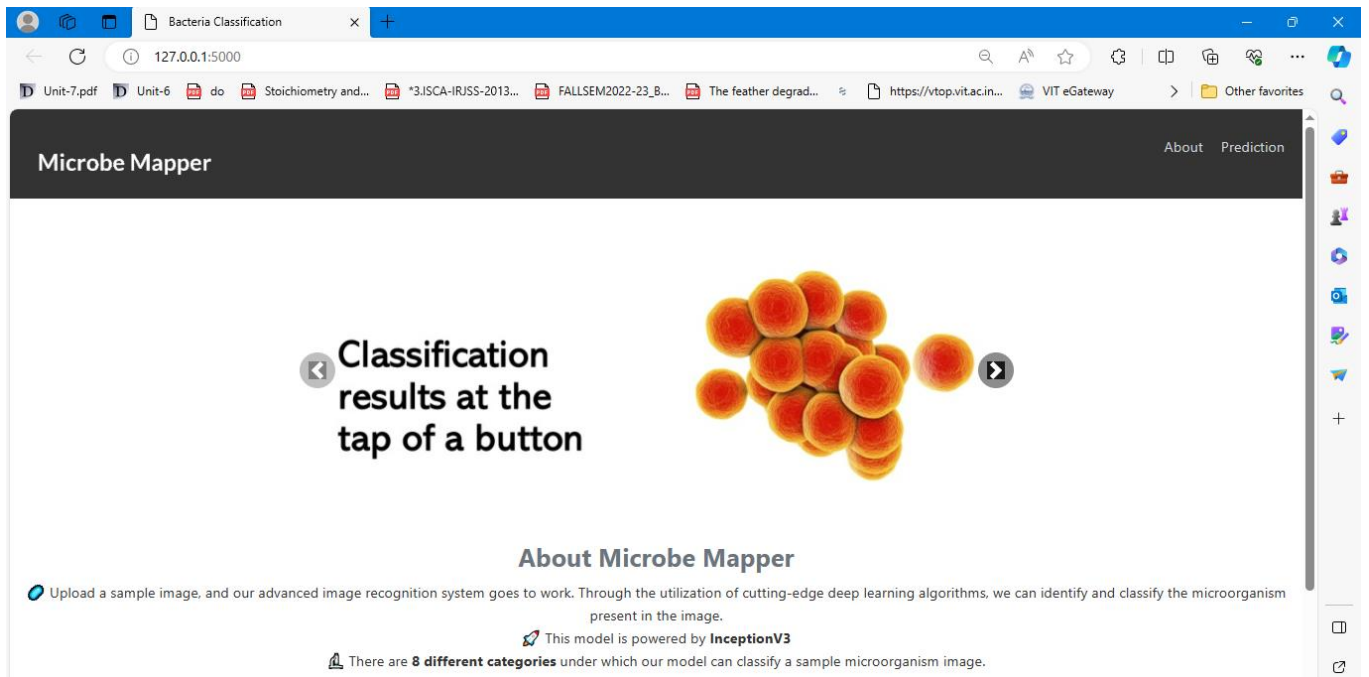
Top Screenshot:

```
Flask > app.py > ...
1  import os
2  from flask import Flask, request, render_template
3  from tensorflow.keras.models import load_model
4  from PIL import Image
5  import numpy as np
6  import matplotlib.pyplot as plt
7  from tensorflow.keras.preprocessing import image
8
9  model = load_model("inception-v3.h5")
10 app = Flask(__name__)
11
12 @app.route('/')
13 def index():
14     return render_template('index.html')
15
16 @app.route('/prediction.html')
17 def prediction():
18     return render_template('prediction.html')
19
20 @app.route('/index.html')
21 def home():
22     return render_template("index.html")
23
24 @app.route('/result', methods=["GET", "POST"])
25 def res():
```

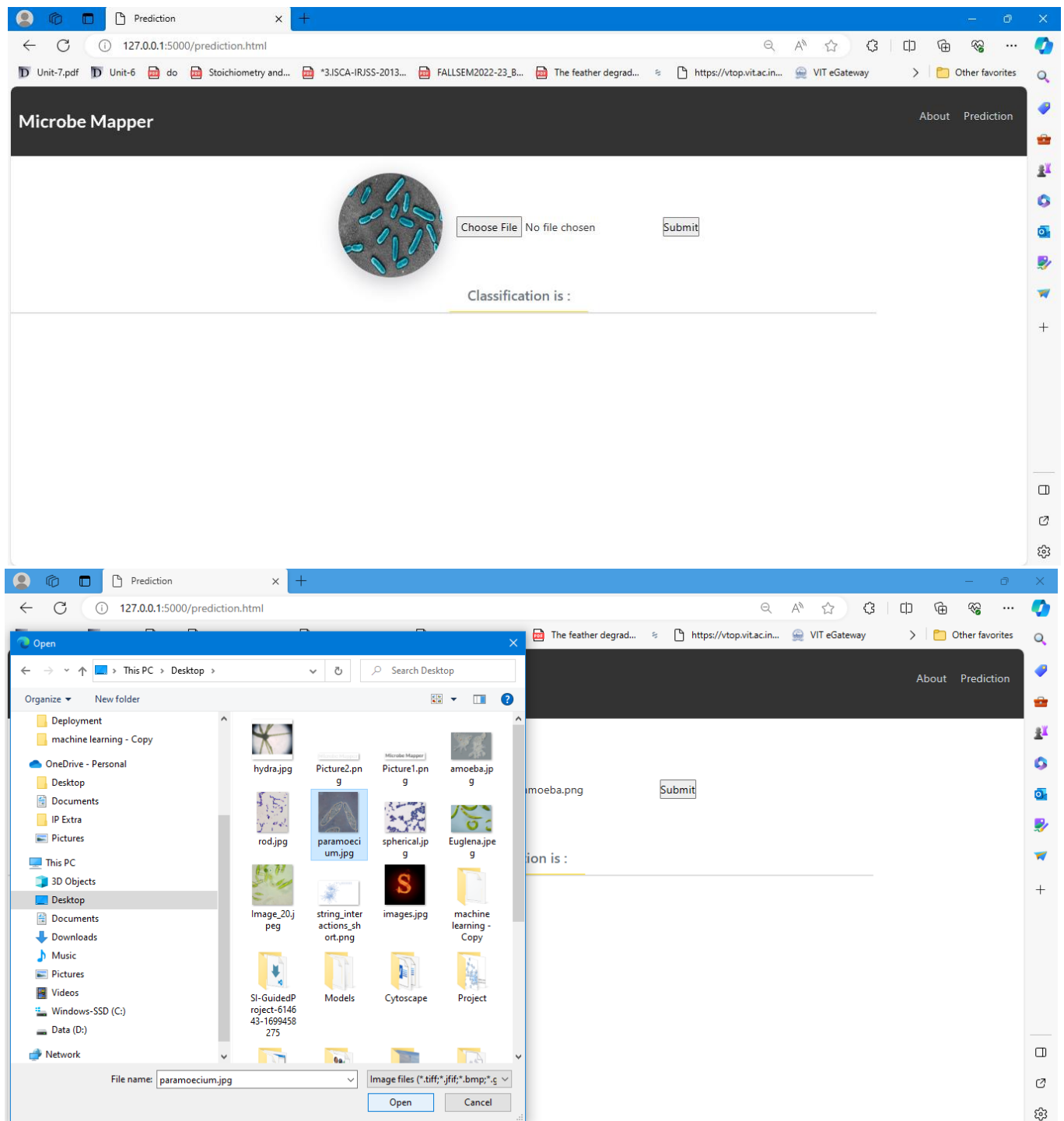
Bottom Screenshot:

```
19
20 @app.route('/index.html')
21 def home():
22     return render_template("index.html")
23
24 @app.route('/result', methods=["GET", "POST"])
25 def res():
26     if request.method == "POST":
27         f = request.files['image']
28         basepath = os.path.dirname(__file__)
29         upload_folder = os.path.join(basepath, 'uploads')
30         if not os.path.exists(upload_folder):
31             os.makedirs(upload_folder)
32
33         filepath = os.path.join(upload_folder, f.filename)
34         f.save(filepath)
35
36         img = Image.open(filepath).convert('RGB')
37         img = img.resize((256, 256))
38         x = np.array(img)
39         x = np.expand_dims(x, axis=0)
40         x = x / 255.0
41
42         predictions = model.predict(x)
43
44         class_names = ['Amoeba', 'Euglena', 'Hydra', 'Paramecium', 'Rod bacteria', 'Spherical bacteria', 'Spiral']
```

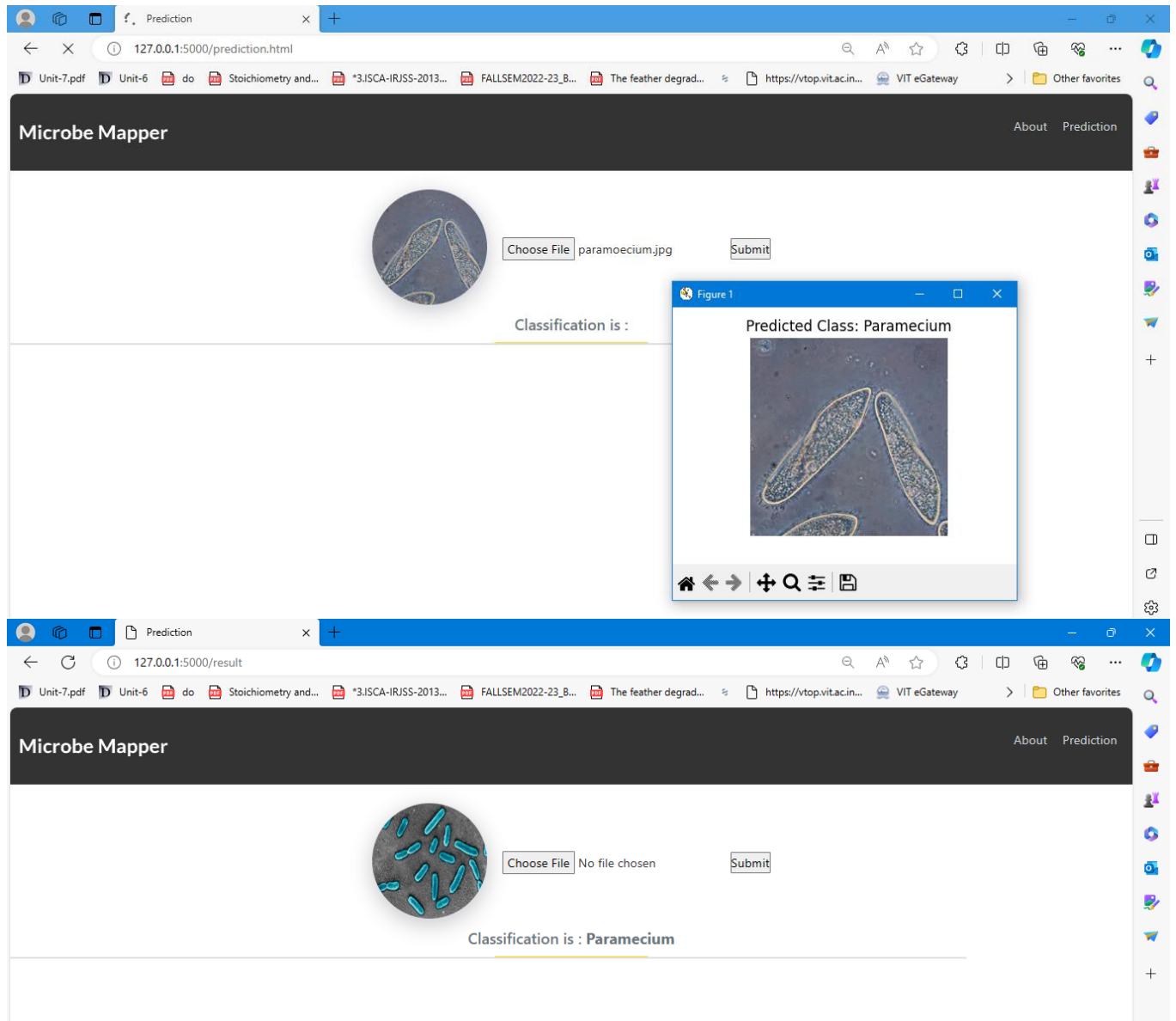

A slider carousel and About Section is displayed on the index.html page:



Finally, the prediction page to upload sample image



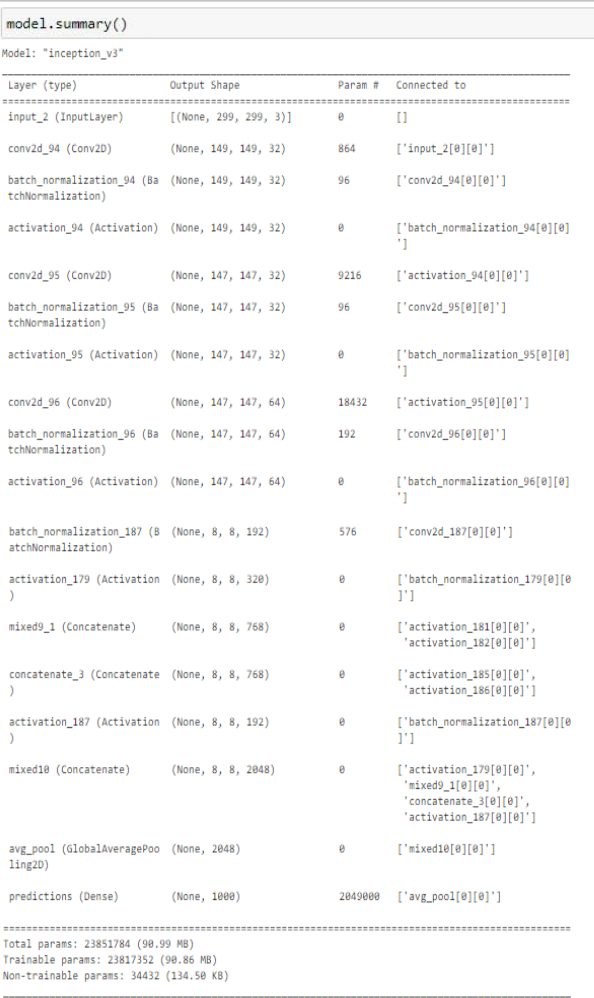
Final Predicted Output (after I click on the Submit Button) is displayed as follows:



The prediction is correct!!

8. PERFORMANCE TESTING

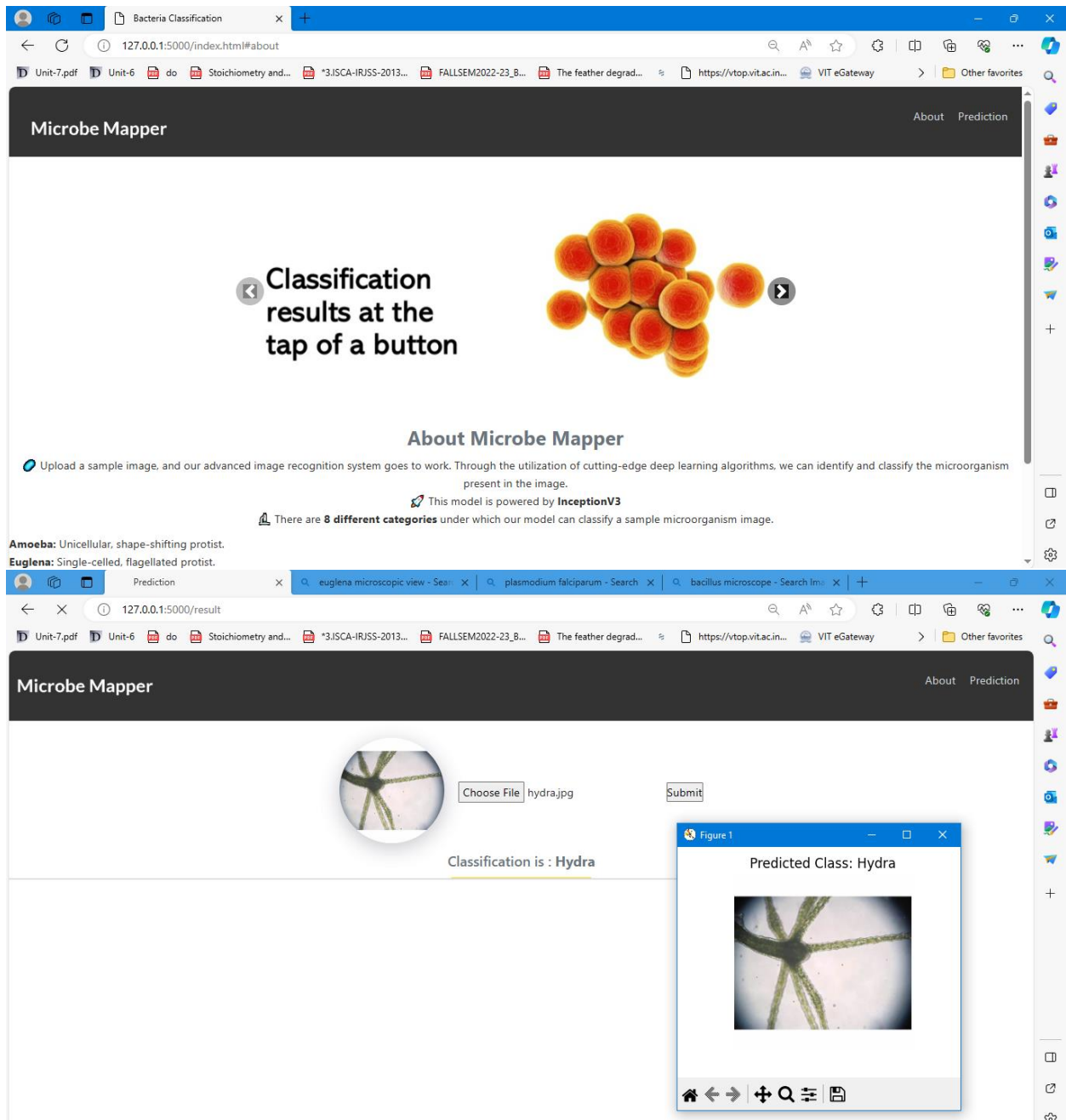
8.1 Performance Metrics

S.No	Parameter	Values	Screenshot
1.	Model Summary	Total params: 23851784 (90.99 MB) Trainable params: 23817352 (90.86 MB) Non-trainable params: 34432 (134.50 KB)	Summary of the Model  <pre>model.summary() Model: "inception_v3" Layer (type) Output Shape Param # Connected to ----- input_2 (InputLayer) [(None, 299, 299, 3)] 0 [] conv2d_94 (Conv2D) (None, 149, 149, 32) 864 ['input_2[0][0]'] batch_normalization_94 (Batch Normalization) (None, 149, 149, 32) 96 ['conv2d_94[0][0]'] activation_94 (Activation) (None, 149, 149, 32) 0 ['batch_normalization_94[0][0]'] conv2d_95 (Conv2D) (None, 147, 147, 32) 9216 ['activation_94[0][0]'] batch_normalization_95 (Batch Normalization) (None, 147, 147, 32) 96 ['conv2d_95[0][0]'] activation_95 (Activation) (None, 147, 147, 32) 0 ['batch_normalization_95[0][0]'] conv2d_96 (Conv2D) (None, 147, 147, 64) 18432 ['activation_95[0][0]'] batch_normalization_96 (Batch Normalization) (None, 147, 147, 64) 192 ['conv2d_96[0][0]'] activation_96 (Activation) (None, 147, 147, 64) 0 ['batch_normalization_96[0][0]'] batch_normalization_187 (Batch Normalization) (None, 8, 8, 192) 576 ['conv2d_187[0][0]'] activation_179 (Activation) (None, 8, 8, 320) 0 ['batch_normalization_179[0][0]'] mixed9_1 (Concatenate) (None, 8, 8, 768) 0 ['activation_181[0][0]', 'activation_182[0][0]'] concatenate_3 (Concatenate) (None, 8, 8, 768) 0 ['activation_185[0][0]', 'activation_186[0][0]'] activation_187 (Activation) (None, 8, 8, 192) 0 ['batch_normalization_187[0][0]'] mixed10 (Concatenate) (None, 8, 8, 2048) 0 ['activation_179[0][0]', 'mixed9_1[0][0]', 'concatenate_3[0][0]', 'activation_187[0][0]'] avg_pool (GlobalAveragePooling2D) (None, 2048) 0 ['mixed10[0][0]'] predictions (Dense) (None, 1000) 2049000 ['avg_pool[0][0]'] Total params: 23851784 (90.99 MB) Trainable params: 23817352 (90.86 MB) Non-trainable params: 34432 (134.50 KB)</pre>

2.	Accuracy	<p>Training Accuracy - 97.68</p> <p>Validation Accuracy - 72.00</p>	<p>Downloading data from https://storage.googleapis.com/tensorflow/keras-applications/inception_v3/inception_v3_weights_tf_dim_ordering_tf_kernels_notop.h5</p> <p>87910968/87910968 [=====] - 0s 0us/step</p> <p>Epoch 1/50</p> <p>6/6 [=====] - 45s 5s/step - loss: 2.0527 - accuracy: 0.2899 - val_loss: 1.5852 - val_accuracy: 0.4133</p> <p>Epoch 2/50</p> <p>6/6 [=====] - 18s 3s/step - loss: 1.4273 - accuracy: 0.4916 - val_loss: 1.1782 - val_accuracy: 0.6400</p> <p>Epoch 3/50</p> <p>6/6 [=====] - 19s 3s/step - loss: 1.0779 - accuracy: 0.6317 - val_loss: 1.0741 - val_accuracy: 0.6267</p> <p>Epoch 4/50</p> <p>6/6 [=====] - 18s 3s/step - loss: 0.9456 - accuracy: 0.6905 - val_loss: 1.0684 - val_accuracy: 0.6267</p> <p>Epoch 5/50</p> <p>6/6 [=====] - 20s 3s/step - loss: 0.8547 - accuracy: 0.6989 - val_loss: 1.0314 - val_accuracy: 0.6800</p> <p>Epoch 6/50</p> <p>6/6 [=====] - 19s 3s/step - loss: 0.7636 - accuracy: 0.7451 - val_loss: 0.9295 - val_accuracy: 0.6933</p> <p>Epoch 7/50</p> <p>6/6 [=====] - 20s 4s/step - loss: 0.6826 - accuracy: 0.7619 - val_loss: 0.9284 - val_accuracy: 0.7200</p> <p>Epoch 8/50</p> <p>6/6 [=====] - 18s 3s/step - loss: 0.5743 - accuracy: 0.8151 - val_loss: 0.9173 - val_accuracy: 0.7467</p> <p>Epoch 9/50</p> <p>6/6 [=====] - 18s 3s/step - loss: 0.5362 - accuracy: 0.8487 - val_loss: 0.9345 - val_accuracy: 0.7067</p> <p>Epoch 10/50</p> <p>6/6 [=====] - 19s 3s/step - loss: 0.4905 - accuracy: 0.8389 - val_loss: 0.9729 - val_accuracy: 0.6933</p> <p>Epoch 11/50</p> <p>6/6 [=====] - 18s 3s/step - loss: 0.4400 - accuracy: 0.8669 - val_loss: 0.9768 - val_accuracy: 0.7200</p>
3.	Confidence Score (Only Yolo Projects)	<p>Class Detected - NA</p> <p>Confidence Score - NA</p>	Not Applicable

9. RESULTS

9.1 Output Screenshots



Prediction

127.0.0.1:5000/result

Unit-7.pdf Unit-6 do Stoichiometry and... *3.JSCA-IRJSS-2013... FALLSEM2022-23_B... The feather degrad... https://vtop.vit.ac.in... VIT eGateway Other favorites

Microbe Mapper

About Prediction

Choose File amoeba.jpg Submit

Classification is : Amoeba

Figure 1

Predicted Class: Amoeba

Figure 1

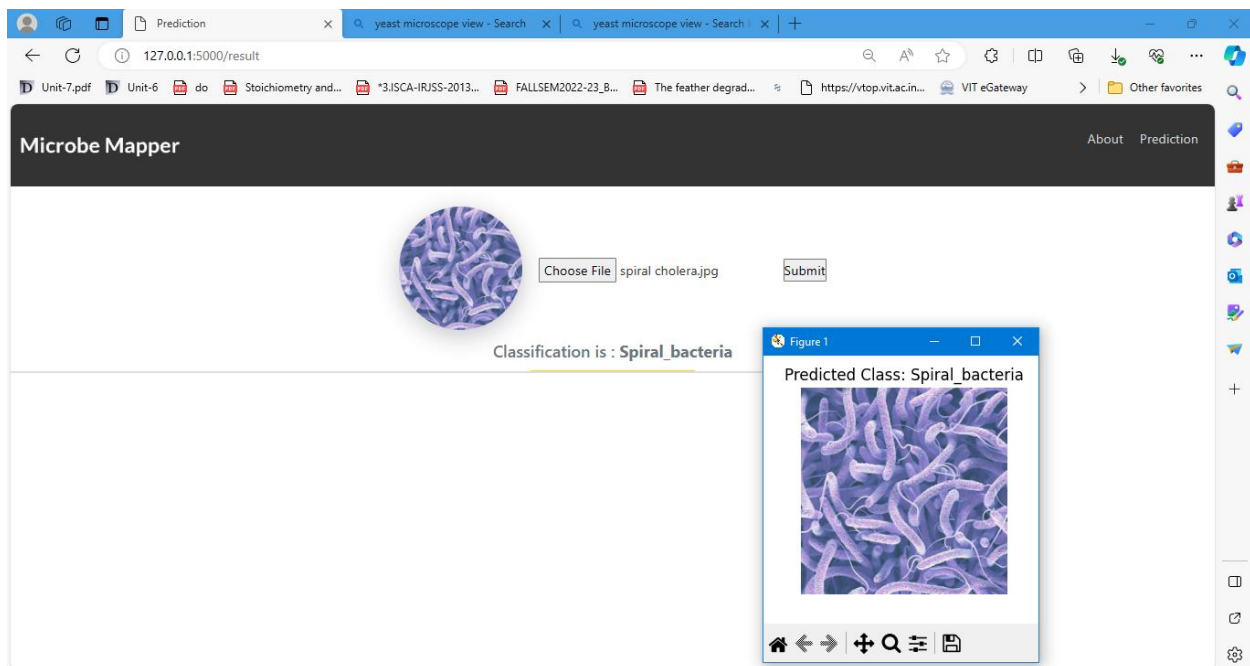
Predicted Class: Yeast

Choose File yeast.jpg Submit

Classification is : Yeast

Figure 1

Predicted Class: Yeast



10. ADVANTAGES & DISADVANTAGES

The current method provides a robust and rapid method for visual recognition of microbes. The Inception v3 can be used as a pre-trained model for transfer learning, which allows researchers to leverage knowledge gained from one task to improve performance on a related task.

The reported training accuracy of 97.68% indicates that the model performed well on the training dataset. However the validation accuracy is reported as 72.00%. There is a notable gap between the training and validation accuracy. Therefore our model poses a possibility of over fitting .

11. CONCLUSION

This project successfully classifies Microbe images by utilising Deep Learning and can be utilised as one of the future methods for rapid microbe sample classification. Nonetheless, certain improvements such as creating new algorithms or increasing the number of epochs or validation steps can be a great breakthrough in the fields of microbiology and pathology.

12. FUTURE SCOPE

The current project acts as an inspiration for future researchers to further improve DL algorithms for microorganisma classification. This method can be integrated to NextGen microscopes to provide live in-situ identification of the organism via the researchers' microscope.

13. APPENDIX

- <https://www.kaggle.com/datasets/mdwaquarazam/microorganism-image-classification/code>
- Zhao P, Li C, Rahaman MM, et al. EMDS-6: Environmental Microorganism Image Dataset Sixth Version for Image Denoising, Segmentation, Feature Extraction, Classification, and Detection Method Evaluation. *Front Microbiol.* 2022;13:829027. Published 2022 Apr 25. doi:10.3389/fmicb.2022.829027
- Zhang J, Li C, Yin Y, Zhang J, Grzegorzec M. Applications of artificial neural networks in microorganism image analysis: a comprehensive review from conventional multilayer perceptron to popular convolutional neural network and potential visual transformer. *Artif Intell Rev.* 2023;56(2):1013-1070. doi:10.1007/s10462-022-10192-7
- Ma P, Li C, Rahaman MM, et al. A state-of-the-art survey of object detection techniques in microorganism image analysis: from classical methods to deep learning approaches. *Artif Intell Rev.* 2023;56(2):1627-1698. doi:10.1007/s10462-022-10209-1
- Rani P, Kotwal S, Manhas J, Sharma V, Sharma S. Machine Learning and Deep Learning Based Computational Approaches in Automatic Microorganisms Image Recognition: Methodologies, Challenges, and Developments. *Arch Comput Methods Eng.* 2022;29(3):1801-1837. doi:10.1007/s11831-021-09639-x

- Zhang J, Li C, Kulwa F, et al. A Multiscale CNN-CRF Framework for Environmental Microorganism Image Segmentation. *Biomed Res Int*. 2020;2020:4621403. Published 2020 Jul 7. doi:10.1155/2020/4621403

GitHub & Project Demo Link

Github :-

<https://github.com/smartinternz02/SI-GuidedProject-614643-1699458275>

Demo Link:-

<https://drive.google.com/drive/folders/1Px76veJTk6aoN4ugv8QpF5m39kOnn58K?usp=sharing>