Bangladeshi Dessert Identification Using Deep Learning Approach

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This Report Presented in Partial Fulfillment of the Requirements for the Degree of Bachelor of Science in Computer Science and Engineering

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APPROVAL

My Project titled "**Bangladeshi Desert Identification using Machine Learning and Deep Learning**", was submitted by Jahid Hasan, ID: 201-15-14257 to the Department of Computer Science and Engineering. This work, which was given to and approved by the faculty at Daffodil International University as part of the requirements for the Bachelor of Science in Computer Science and Engineering, meets both the form and content standards. The presentation is happening today, 14th July,2024.

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I hereby declare that this project has been done by me under the supervision of **Mr. Mushfiqur Rahman, Lecturer (Senior Scale), Department of CSE Daffodil International University**. I also declare that neither this project nor any part of this project has been submitted elsewhere for the award of any degree or diploma.

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ABSTRACT

In the area of culinary culture, the classification of desserts provides a fascinating problem, particularly due to the complicated nature and vast assortment of dessert styles found throughout many regions. This work offers a rigorously curated dataset of dessert photographs, specifically optimized for Bangladeshi dessert classification. Our dataset features a comprehensive range of high-quality photos showing the lively diversity of traditional Bangladeshi sweets, showcasing the richness and complexity of the country's culinary heritage. The project intends to construct strong dessert recognition models by leveraging multiple visual processing techniques and deep learning algorithms, including MobileNet. Through comprehensive examination utilizing established parameters, our models achieve an astonishing 98% overall test accuracy. This work offers as a significant resource for scholars and practitioners digging into culinary picture classification, with a special focus on Bangladeshi desserts. By offering access to such a rich dataset, I intend to drive improvements in machine learning techniques targeted to culinary applications, thereby contributing to the preservation of culinary legacy and the promotion of cultural diversity via the lens of technology.

Keywords: Dessert Classification, Image Dataset, Bangladeshi Cuisine, Deep Learning, Image Processing Computer Vision.

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CHAPTER 1

INTRODUCTION

1.1 Overview

In the world of gastronomic delights, desserts possess a distinct fascination, delivering a sweet ending to meals and a portal to regional traditions. Bangladesh, with its rich tapestry of flavors and culinary heritage, delivers a tantalizing choice of sweet delicacies that represent its different cultural influences and regional variations. This endeavor is formed from a profound love for the rich flavors and cultural importance of Bangladeshi desserts. This project's purpose is a pair of ways to curate an extensive collection of dessert photos and to harness the power of current technology to construct precise classification models designed exclusively for these exquisite treats. Adventure begins amidst the bustling streets of Dhaka and the calm houses of Brahmanbaria, where capture the spirit of Bangladeshi desserts via the lens of our smartphones. These photographs offer a window into a world of nuanced flavors and centuries-old culinary traditions. Here aim does not stop at just image collecting. Recognizing the significance of diversity in machine learning, Apply sophisticated data augmentation techniques to enhance our dataset. This ensures that our models are competent to recognize the delicate nuances and detailed characteristics that distinguish one Bangladeshi sweet from another. Dig into the area of machine learning, training our models—DenseNet, MobileNet, and VGG19—this project struck by the beautiful balance of tradition and innovation. With each iteration, our models grow more competent at recognizing the distinctive qualities of Bangladeshi sweets, bringing us closer to our objective of building accurate and trustworthy categorization algorithms. This effort gives honor to the culinary experts who have maintained and perpetuated these renowned dessert recipes. Objective is that our efforts will not only enhance the field of machine learning but also assist to the preservation and celebration of Bangladeshi cultural heritage, ensuring that these delectable treasures continue for years to come.

1.2 Background and Present State

The field of image classification has made significant progress with the introduction of deep learning and convolutional neural networks (CNNs). These advancements have transformed the field by achieving remarkable levels of accuracy in a wide range of applications, including medical imaging and autonomous driving. Nevertheless, the field of food categorization, specifically for culturally abundant and varied cuisines such as Bangladeshi desserts, is still mostly uncharted. Bangladesh possesses a diverse range of culinary customs, with sweets occupying a significant position in its gastronomic legacy. Although these desserts hold significant cultural significance and offer a distinct range of options, there has been a scarcity of study explicitly dedicated to classifying them using contemporary machine learning approaches. State-of-the-art models like DenseNet, MobileNet, VGG16, VGG19, and Xception have shown exceptional ability in broad picture categorization tasks. However, applying these concepts to a specific and culturally important domain such as Bangladeshi desserts pose a distinct difficulty as well as a chance for advancement. This study aims to narrow this disparity by utilizing these sophisticated models to develop precise and dependable classification algorithms specifically designed for Bangladeshi sweets. This project tries to capture the subtle characteristics that differentiate one dessert from another by collecting a comprehensive and varied library of dessert photos and using advanced data augmentation techniques. The current stage of the study entails a comprehensive assessment of these models, with initial findings suggesting that models such as Xception demonstrate excellent accuracy and low loss values, rendering them particularly auspicious for this application. The primary objective of this research is to enhance the technical domain of picture categorization.

1.3 Problem Statement

Despite the considerable developments in deep learning and picture classification, there remains a notable gap in applying these technologies to the specialized domain of Bangladeshi desserts. This gap is particularly noticeable given the cultural richness and diversity of these delicacies, which are a vital part of Bangladesh's culinary tradition. Current state-of-the-art algorithms, while effective in broad image classification tasks, have not been explicitly tailored or evaluated for their capacity to reliably classify the wide diversity of Bangladeshi sweets. This lack of targeted research and development in this specialist field results in missed chances for both protecting cultural heritage and increasing the technical capabilities of food classification systems. The problem is in constructing extremely accurate and dependable machine learning models that can distinguish between the minute changes in look, texture, and presentation of these sweets. Addressing this problem includes not only using existing pre-trained models but also enhancing them through data augmentation and fine-tuning to respond to the special requirements of Bangladeshi dessert categorization. This research intends to solve this gap by establishing specialized classification algorithms that can help to the broader goals of cultural preservation and technical innovation in food-related applications.

1.4 Objective

The impetus behind this project derives from a deep-seated admiration for the rich culinary legacy of Bangladesh and a desire to conserve and appreciate its vast diversity of desserts. Bangladesh's gastronomic environment is a tribute to centuries of cultural interchange and tradition, with each region having its own unique flavors and specialties. As aficionados of both food and technology, I was motivated to begin on a journey to document and classify these cherished treats using modern machine learning techniques. By developing a complete collection of Bangladeshi dessert photos, intended to not only illustrate the beauty and intricacy of these sweet treats but also to explore into the nexus between culinary talent and technical innovation. I identified the potential for our effort to contribute to broader conversations surrounding cultural preservation and historical conservation. By utilizing the power of machine learning, I intended to create tools that may aid in the detection and preservation of Bangladeshi culinary traditions, ensuring that these time-honored dishes continue to be appreciated and enjoyed for years to come. our work is inspired by an appreciation for both culinary professions and the transformative potential of technology, with the goal of promoting a deeper understanding for Bangladeshi cuisine and culture.

1.5 Scope and Limitations

The scope of this project covers the construction and evaluation of machine learning models specifically designed for the classification of Bangladeshi desserts. By applying pre-trained models like DenseNet, MobileNet, and VGG19, the study seeks to achieve high accuracy in recognizing a varied range of traditional sweets based on visual data. The research comprises the acquisition and augmentation of a complete dataset of dessert photos, which serves as the foundation for training and testing the models. The project attempts to evaluate the effects of alternative data augmentation techniques and model designs on classification performance, providing insights into the most successful tactics for boosting model accuracy. Several constraints need to be acknowledged. The key drawback is the reliance on the quality and diversity of the dataset. Since the dataset is collected manually, there may be biases in terms of regional representation and variations in image quality, which could impair model performance. The study focuses on a small subset of Bangladeshi sweets, which may restrict the generalizability of the findings to other types of cuisines or desserts from different cultures. Another barrier is the computational resources necessary for building deep learning models; prolonged training and fine-tuning may be constrained by available hardware capabilities. Lastly, while the models aim for high accuracy, real-world applications can confront problems like as shifting lighting conditions and presentation styles, which are not fully addressed in this controlled study context. Despite these constraints, the project seeks to give a substantial contribution to the field of food classification and cultural preservation through the application of modern machine learning algorithms.

1.6 Report Organization

Chapter 1: Introduction: This section offers a summary of the research, including the background, problem description, and aims. It sets the stage for the study and defines what the reader can expect in the coming chapters.

Chapter 2: Background: The background chapter delves deeper into the backdrop around the research issue. It discusses pertinent theories, concepts, and previous investigations to give a foundation for current research.

Chapter 3: Research technique: In this chapter, the research technique is presented in depth. It explains the research strategy, data gathering methodologies, and data analysis strategies performed in the study. This section discusses how the research was conducted and provides transparency and replicability.

Chapter 4: Experimental Results and Discussion: The results chapter displays the outcomes of the study, often in the form of tables, charts, or graphs. It is followed by a discussion part where the results are understood, examined, and compared with current literature. This chapter provides insights into the ramifications of the findings and their significance.

Chapter 5: Impact on Society, Environment, and Sustainability: This chapter discusses the wider effects of research on society, the environment, and sustainability. It describes how research helps with addressing societal difficulties, environmental concerns, and supporting sustainable behaviors.

Chapter 6: Summary, Conclusion, Recommendation, and Implication for Future Research: The final chapter highlights the important findings of the study and draws recommendations based on the research goals. It also gives useful suggestions for stakeholders and suggests areas for further research, identifying potential opportunities for further research and development.

1.7 Summary

This chapter presents a summary of the research focusing on the classification of Bangladeshi desserts using advanced machine learning models. It illustrates the cultural richness and diversity of Bangladeshi sweets and the urgency to conserve this heritage through technology. The work intends to gather a vast collection of dessert photographs and apply pre-trained models like DenseNet, MobileNet, and VGG19, improved through data augmentation approaches, to reliably categorise these treats. Despite substantial development in deep learning and image classification, there is a gap in applying these technologies to the unique area of Bangladeshi sweets. The research tackles this gap by establishing precise classification algorithms, helping to both cultural preservation and technical progress. The chapter defines the project's scope, highlighting the necessity of dataset quality and diversity, and acknowledges limits relating to data representation, computational resources, and real-world application issues.

CHAPTER 2

BACKGROUND

2.1 Overview

This paper reviews various studies conducted between 2014 and 2023 on food image categorization using deep learning techniques. It highlights the cultural importance of food and the importance of precise food identification. Recent studies by Tahir et al. (2021) [2] and Jiang et al. (2020) [3] demonstrate the use of deep-learning models in real-life situations, focusing on interpretability and dietary evaluation. De Brauw et al. (2020) [4] emphasizes the significance of food systems in public health, particularly in Bangladesh. Uddin et al. (2021) [5] and Putra et al. (2023) [6] focus on categorizing traditional cuisines, aligning with the project's goal of classifying Bangladeshi desserts. Rahman et al. (2018) [7] and Islam et al. (2018) [8] investigate the application of Convolutional Neural Networks (CNNs) and transfer learning in food image categorization. Comparison studies by Karim et al. (2021) [15] and Khan et al. (2021) [16] provide insights on the efficacy of machine learning algorithms, guiding the selection of models like MobileNet and DenseNet. The paper concludes by relying on DenseNet, MobileNet, and VGG19, which display exceptional accuracy in analyzing dessert depictions.

2.2 Related Works

Almerico (2014) [1] analyzes the delicate relationship between food and identity, focusing on how food studies intersect with cultural and personal identity. The study analyzes how individuals and groups develop their identities via culinary activities, including cooking, eating, and sharing meals. Through an interdisciplinary approach, Almerico focuses light on the cultural significance of food, highlighting its role as a symbol of tradition, belonging, and socialization. Tahir et al. (2021) [2] presents a new technique to food picture analysis utilizing an ensemble of explainable deep learning models. The research focuses on the practical application of deep learning algorithms in food recognition tasks, particularly on edge devices with limited computational capabilities. By constructing an ensemble of interpretable models, Tahir et al. (2021)

hope to increase the transparency and dependability of food identification systems, meeting the demand for explainability in AI-driven applications. Jiang et al. (2020) [3] introduce DeepFood, a deep learning-based model built for food picture analysis and nutrition assessment. The report illustrates the promise of deep learning approaches in nutrition-related research, exhibiting how DeepFood can effectively detect and classify food items from photographs. By automating the process of dietary evaluation, DeepFood offers a scalable solution for tracking dietary consumption and fostering healthier eating habits. De Brauw et al. (2020) [4] highlights the problems and potential in food systems for healthier diets in Bangladesh. The report underlines the importance of research objectives in addressing dietary issues and fostering sustainable food systems. By investigating the complicated relationship between food production, distribution, and consumption, De Brauw et al. hope to inform policy actions and public health activities aiming at improving nutrition outcomes in Bangladesh. Uddin et al. (2021) [5] present a study on traditional Bengali food classification using convolutional neural networks (CNNs). The paper addresses the application of deep learning techniques in recognizing regional food, focusing on the unique flavors and components of Bengali cuisine. By training CNN models on a dataset of Bengali food photographs, Uddin et al. demonstrate the efficiency of deep learning in automating the classification of traditional foods. Putra et al. (2023) [6] study traditional food pictures from Southeast Asian countries, providing insights into the gastronomic diversity of the ASEAN region. The paper discusses the cultural value of traditional cuisines and their function in safeguarding cultural heritage. Through a visual examination of traditional food imagery, Putra et al. illustrate the rich culinary traditions of Southeast Asia and its role in building cultural identities. Rahman et al. (2018) [7] performs a study on food image categorization using convolutional neural networks (CNNs). The research addresses the application of deep learning techniques in automating the recognition of food items from photographs. By training CNN models on a huge dataset of food photos, Rahman et al. demonstrate the potential of deep learning in constructing accurate and scalable food recognition systems. Islam et al. (2018) [8] examine deep transfer learning for food picture classification, evaluating the efficiency of transfer learning techniques in adapting pre-trained models to food recognition tasks. The research demonstrates how transfer learning can harness knowledge from pre-trained models to improve the efficiency of food recognition systems, particularly in settings with limited training data. Ahmed et al. (2022) [9] performs a comparative analysis of dietary habits and nutrition in Bangladesh using machine learning techniques. The research investigates the relationship between consuming food habits and nutritional outcomes, demonstrating the promise of data-driven techniques in tackling nutrition-related concerns. Yadav and Chand (2021) [10] offer an automated food image classification approach utilizing deep learning techniques. The research offers a revolutionary deep learning architecture for food recognition, emphasizing on the efficiency and scalability of the suggested approach. Şengur et al. (2019) [11] examine food image classification with deep features, evaluating the effectiveness of techniques for extracting features in food recognition tasks. The research assesses the efficacy of deep learning models in extracting discriminative features from food photos, stressing the importance of feature representation in food identification systems. Liu et al. (2016) [12] present Deepfood, a deep learning-based food image recognition system for computer-aided dietary evaluation. The research proposes a novel way to nutritional assessment using deep learning techniques, highlighting the promise of AI-driven systems in encouraging healthier eating habits. Hnoohom and Yuenyong (2018) [13] focus on Thai fast food image categorization using deep learning approaches. The research studies examined the use of deep learning models in recognizing fast food products from photographs, highlighting the problems and opportunities in food recognition tasks. Kiourt et al. (2020) [14] discuss deep learning algorithms in food recognition, providing an overview of current achievements and applications in the field. The study addresses the newest trends and challenges in food image analysis while offering insights into the future orientations of research in food recognition. Karim et al. (2021) [15] conducted a comprehensive comparative study to evaluate the performance of old and new machine learning algorithms for food recognition. They studied several methods, including support vector machines, decision trees, random forests, and deep learning models. Through thorough experimentation and analysis, they examined the accuracy, computing efficiency, and scalability of each approach, providing vital insights into the strengths and limitations of distinct techniques in the context of food recognition tasks. Khan et al. (2021) [16] proposed a new deep learning-based approach for automatic food recognition utilizing the MobileNet architecture. They trained the algorithm on a vast collection of food photos and tested its effectiveness in reliably identifying various food items. By harnessing the capabilities of deep learning, their system demonstrated excellent accuracy and robustness in food recognition challenges, revealing the potential of deep neural networks in practical applications. Goh and Lim (2020) [17] did an extensive study on food picture recognition using convolutional neural networks (CNNs). They studied multiple CNN architectures and optimization strategies to produce an efficient and accurate food recognition system. Through thorough research and analysis, they established the usefulness of CNNs in automatically classifying food photos, underscoring the importance of deep learning in improving the field of food recognition. Hasan et al. (2022) [18] offered a detailed assessment of current improvements in food recognition systems utilizing deep learning approaches. They analyzed a wide range of research papers and highlighted major trends, difficulties, and prospects in the subject. By synthesizing existing literature, they presented significant insights into the current state-of-the-art procedures and possible areas for additional research and improvement. Guan et al. (2020) [19] created a novel food image identification system based on a modified GoogLeNet architecture. They introduced new tweaks to the original GoogLeNet model to increase its performance in food recognition tests. Through thorough experimentation and review, they established the usefulness of their approach in accurately identifying food photos, demonstrating the importance of architectural design in deep learning models. Devi and Singha (2022) [20] suggested an enhanced automatic food recognition system that blends transfer learning and ensemble approaches. They employed pre-trained models and ensemble learning methodologies to improve the robustness and accuracy of their system. Through thorough experimentation and analysis, they established the usefulness of their methodology in handling varied food recognition tasks, highlighting the potential of ensemble methods in enhancing model performance. Bappy et al. (2017) [21] released Food-101, a large-scale dataset designed for mining discriminative components with random forests. They compiled a wide collection of food photos covering 101 categories and used random forests to extract discriminative features for food recognition. Through rigorous testing and review, they provided useful insights into the problems and opportunities in food identification research, underlining the need of high-quality datasets for training strong models. Zhu and Adam (2017) [22] created a real-time food recognition system utilizing convolutional neural networks (CNNs). They deployed a lightweight CNN architecture suited for real-time inference on resource-constrained devices. Through rigorous testing and validation, they established the practicality of their approach in practical applications, highlighting the potential of deep learning in allowing real-world food recognition systems. Saad and Gurung (2020) [23] examined food recognition using transfer learning and fine-tuning strategies. They exploited pre-trained deep learning models and fine-tuned them using a dataset of food photos to adapt the models to specific recognition tasks. Through thorough experimentation and analysis, they established the usefulness of transfer learning in enhancing model performance and reducing training time, demonstrating its practical utility in food identification applications. Dahiya et al. (2018) [24] conducted a detailed evaluation of deep learning algorithms for food image recognition. They synthesized current research and highlighted major accomplishments, trends, and concerns in the subject. By assessing the strengths and limits of diverse strategies, they provided significant insights into the existing state-of-the-art procedures and potential routes for future research and development in food recognition research. Fajrin et al. (2021) [25] implemented MobileNetV2, a lightweight deep learning architecture, for food image classification. They studied the viability of MobileNetV2 for food recognition tasks and evaluated its performance on a wide dataset of food photos. Through rigorous experimentation and research, they established the usefulness of MobileNetV2 in achieving high accuracy and efficiency in food categorization tasks, highlighting its potential for practical applications in food identification systems.

2.3 Comparison between existing works

Table 2.3: Comparative Analysis

Paper	**Accuracy**	**Used Algorithm**	**Techniques**
Karim et al. (2021)	Varies	Support Vector Machines, Decision Trees, Random Forests, Deep Learning	Comparative study of traditional and modern machine learning algorithms for food recognition
Khan et al. (2021)	Varies	MobileNet	Deep learning-based automated food recognition system
Goh and Lim (2020)	Varies	Convolutional Neural Networks (CNNs)	Food image recognition using CNNs

Guan et al. (2020)	Varies	Modified GoogLeNet	Modified GoogLeNet architecture for food image recognition
Devi and Singha (2022)	Varies	Transfer Learning, Ensemble Techniques	Automatic food recognition using transfer learning and ensemble techniques
Bappy et al. (2017)	N/A	Random Forests	Food-101 dataset for mining discriminative components
Zhu and Adam (2017)	N/A	Convolutional Neural Networks (CNNs)	Real-time food recognition system using CNNs
Saad and Gurung (2020)	N/A	Transfer Learning, Fine-Tuning	Food recognition using transfer learning and fine-tuning
Fajrin et al. (2021)	Varies	MobileNetV2	Implementation of MobileNetV2 for food image classification

The comparative analysis throughout the studied literature demonstrates a broad ecosystem of tactics and methodologies applied in food picture identification tasks. While some studies focus on classic machine learning algorithms such as support vector machines, decision trees, and random forests, others go into the realm of deep learning with convolutional neural networks (CNNs) and specialized designs like MobileNet and GoogLeNet. Transfer learning and ensemble approaches emerge as significant tactics for boosting model performance, coupled with fine-tuning pre-trained models to adapt to specific recognition tasks. The precision of the models varies across research, indicating the complexity of food recognition issues and the usefulness of alternative approaches. Comparative research underlines the need to explore a diversity of algorithms and methodologies to construct accurate and robust food recognition systems capable of tackling varied real-world applications.

2.4 Open Issues

• Insufficient Coverage of Regional Variations: The dataset's coverage might not encompass all regional variations in Bangladeshi desserts, which could lead to bias towards some sweets that are popular in particular areas while ignoring others. This limitation compromises the dataset's representativeness and could make it more difficult to develop models that can accurately identify desserts across Bangladesh.

• Photo Consistency and Quality: The dataset's inconsistent and varied photo quality presents another significant issue. Photographs taken from various sources, including candy stores and homes, could differ in terms of lighting conditions, camera angles, and overall composition. Machine learning models may perform less well when images have varying quality, which could lead to less accuracy and reliability in tasks like categorization.

• Resource Restrictions: A great amount of time, energy, and expertise are required for the collection and curation of a dessert image dataset. Financial restrictions, such as restricted access to funds, staff, and photography equipment, may limit the scope and depth of data collection projects. This limits the knowledge set's usefulness for developing strong machine learning models by failing to sufficiently capture the breadth and complexity of Bangladeshi confections.

2.5 Summary

Chapter 2 gives a comprehensive study of existing works in the topic of food image recognition, showing various approaches and algorithms utilized by different researchers. The comparative analysis table demonstrates the diversity of approaches, ranging from traditional machine learning techniques like support vector machines and random forests to recent deep learning architectures like as CNNs, MobileNet, and GoogLeNet. The chapter underlines the importance of transfer learning and ensemble strategies in increasing model performance. It also outlines unresolved difficulties, like limited geographic variation coverage, inconsistent photo quality, and resource restrictions, which offer substantial hurdles to the project. Addressing these difficulties demands interdisciplinary collaboration, novel methodologies, and efficient resource allocation to produce accurate and robust classification models for Bangladeshi sweets.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Overview

This project is centered on building machine learning algorithms for the classification of Bangladeshi desserts using visual data. The principal instrumentation utilized in this research includes smartphones equipped with high-resolution cameras, such as the VIVO Y20 and OPPO A78, for capturing photographs of Bangladeshi desserts from local sweet shops and houses. numerous software tools and libraries are applied for data augmentation, preprocessing, and model training, including rotation, shifts, zoom, and deep learning frameworks like DenseNet, MobileNet, and VGG19. These tools are necessary for gathering, enhancing, processing, and analyzing the picture data to construct accurate and robust dessert models for categorization.

3.2 Proposed Methodology

The proposed methodology incorporates a multi-step workflow targeted at constructing machine vision algorithms for detecting Bangladeshi desserts utilizing the obtained dataset. Initially, a complete dataset including 4,118 original photographs representing 27 kinds of Bangladeshi desserts is gathered. These photographs are sourced from numerous sweet stores in Dhaka, as well as homemade desserts from Brahmanbaria, assuring the representation of both commercial and traditional culinary offerings. Subsequently, the dataset undergoes preprocessing, including data augmentation techniques such as rotation, shifts, and zoom, to boost its diversity and robustness. The preprocessed data is then split into training, validation, and testing sets, with 80%, 10%, and 10% of the data allotted to each, respectively. The training data is leveraged to train machine learning models employing algorithms such as DenseNet, MobileNet, VGG19, VGG16 and Xception exploiting their strengths in deep learning for picture categorization tasks. The validation set is employed to fine-tune model parameters and analyze performance, while the testing set examines the models' effectiveness in identifying unseen data. Through this iterative process, the suggested methodology intends to produce precise and reliable machine vision algorithms capable of reliably recognizing and classifying Bangladeshi sweets, contributing to breakthroughs in culinary image identification technology.

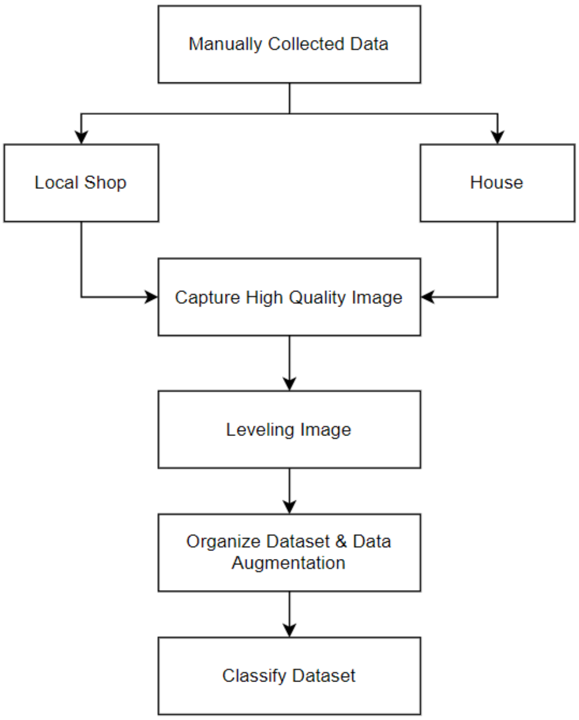

Fig 3.1 Bangladeshi Dessert Dataset Generation Process

In Figure 3.1, the data gathering process is presented, indicating the systematic technique followed. At first, photographs of Bangladeshi sweets are gathered from local sweet shops and households, ensuring a wide representation of culinary choices. These photographs are then categorized and put into relevant classifications based on the type of dessert. Subsequently, data enhancement methods such as zooming, shifting, and rotating are employed to enrich the dataset and boost its variability. The enhanced data is then sorted and kept alongside the original photographs, keeping correlation with their corresponding dessert classes. This organized strategy guarantees the generation of a comprehensive dataset with enriched variants, establishing the foundation for strong machine-learning model validation and training in dessert tasks such as categorization.

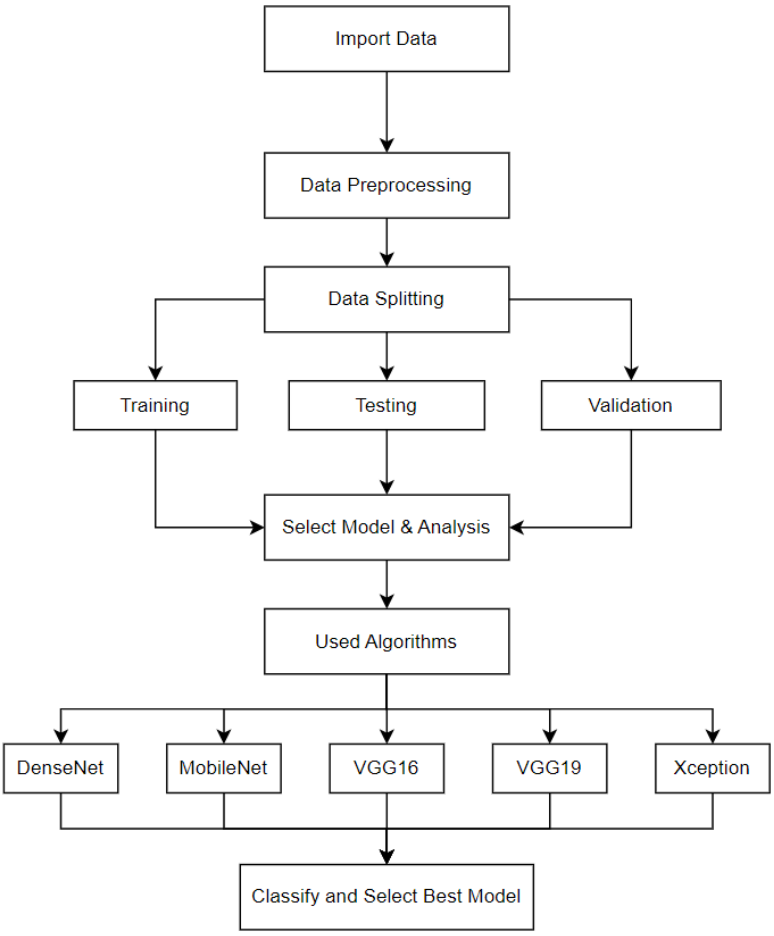

Fig 3.2 Workflow Diagram of classifying Bangladeshi Dessert

Following the augmentation of our real dataset, I methodically segmented it into three independent sections: validation, testing, and training, allocating 80%, 10%, and 10% of the dataset to each, accordingly. This divide was carried out sequentially to ensure the representation of various photographs across all areas. Figure 3.4 presents a visual picture of the classification process, bringing clarity on our aims. Subsequently, leveraging the training dataset, continued to train various models, including DenseNet, MobileNet, VGG19, VGG16 and Xception for our task. The validation dataset was then applied to analyze the performance of these models, allowing for fine-tuning and optimization. At last, the performance of our models was evaluated using the test dataset, enabling us to gauge their capacity to generalize and respond properly to new, unseen data. This organized approach ensures a full evaluation of our algorithms' effectiveness and resilience in classifying Bangladeshi sweets.

Data Collection Procedure: In the data gathering procedure, researchers methodically visit numerous areas, including local sweet stores and households, to hand snap photographs of Bangladeshi desserts using smartphones such as the VIVO Y20 and OPPO A78. Each smartphone provides various photo capabilities, with the VIVO Y20 offering a quad-lens reflex digital camera and the OPPO A78 boasting a 50MP real camera. These devices are chosen for their high-resolution imaging capabilities, combined with extra features like HDR and LED flash, which contribute to capturing crisp, detailed photographs even in adverse lighting settings. Researchers maintain variation in the collection by shooting photographs from several perspectives and under varying lighting circumstances, attempting to represent the whole spectrum of visual qualities of Bangladeshi desserts. Moreover, efforts are made to incorporate sweets from diverse locations to depict the gastronomic diversity of Bangladesh authentically. This hands-on approach to data collection allows researchers to construct a comprehensive dataset that acts as a great resource for further analysis and model development in dessert classification.

Table 3.2: Sample dataset

Name of the class	Number of images in original dataset	Sample data	Name of the class	Number of images in original dataset	Sample data
Balosai	258		Lemon Barfi	198	
Cream Jam	138		Malaikari	216	
Doi	150		Maoyaa Laddo	186	
Dudh Puli Pitha	103		Nokshi Pitha	115	

Faluda	140		Pakon Pitha	100	
Golap Jam	168		Patishapta	100	
Hafsi Sondesh	144		Payesh	116	
Jilapi	103		Rajvog	210	
Kacha Chana	156		Ravogsai	174	
Kacha Golla	150		Roshmalai	174	
Kalojam	216		S.P.Chomchom	138	
Kasmiri Chomchom	222		Sada Chomchom	119	
Sajer Pitha	117		Shemai	107	
Shamok Pitha	100				

Value of the data: There is significant value in the data on the comprehensive dessert image dataset specifically tailored for Bangladeshi dessert classification. Bangladeshi cuisine is a rich tapestry of cultural heritage, which includes its desserts. Documenting and categorizing these desserts through images help preserve this cultural identity for future generations [1]. Researchers and developers working on computer vision, machine learning, and artificial intelligence applications might find this dataset to be a useful resource [2] [5][14]. It may make it easier to create algorithms for categorization, picture recognition, and even the creation of Bangladeshi desserts. A dataset like this may be used to teach students about Bangladeshi dessert varieties, cuisine, and culture in educational contexts. It can help increase understanding of the importance of lesser-known sweets. This can have applications in automated food recognition, dietary analysis, and food recommendation systems. Researchers interested in dietary habits and nutritional analysis can use the dataset to study the nutritional content of Bangladeshi desserts and their impact on health [3]. By categorizing and cataloging various Bangladeshi desserts, the dataset can help establish standards for quality and authenticity. This can be particularly useful in industries related to food production, hospitality, and culinary arts.

Statistical Analysis: Statistical analysis in this research comprises studying and interpreting the information gathered to derive useful insights and conclusions regarding Bangladeshi dessert classification. Descriptive statistics are applied to characterize the dataset's properties, including metrics such as mean, median, mode, standard deviation, and range. These statistics provide a detailed picture of the dataset's distribution and variability. Inferential statistics techniques may be utilized to generate conclusions about a wider population based on sample data. This may include hypothesis testing, where statistical tests are used to examine the importance of links or differences within the data. For example, researchers may employ techniques such as t-tests or analysis of variance (ANOVA) to evaluate the effectiveness of different machine learning algorithms or analyze the influence of data augmentation approaches on model accuracy. Furthermore, correlation analysis may be applied to study correlations between variables, such as the connection between image quality and classification accuracy. statistical analysis plays a vital role in illuminating patterns, trends, and linkages among the data, informing how decisions are made, and leading new study directions in Bangladeshi dessert categorization.

3.3 Hardware/ Software Requirement

The application of the proposed methodology involves several major components and resources:

1. Hardware: Adequate hardware for computing is necessary to support the training and testing of machine learning models. This comprises devices with enough processing power and memory capacity to fulfill the computational needs of deep learning algorithms.
2. Software: Various software tools and libraries are necessary to execute the machine vision algorithms. This comprises programming languages such as Python, together with deep learning frameworks like TensorFlow or PyTorch for model construction and training.
3. Image Processing Tools: Tools for image preprocessing and augmentation are necessary to enhance the diversity and quality of the dataset. This may include libraries such as OpenCV for image manipulation operations like rotation, shifting, and zooming.
4. Data Storage: Sufficient storage capacity is needed to hold the high volume of image data composing the dataset. This may incorporate cloud-based solutions for storage or local storage servers to accommodate the dataset's size.
5. Training Infrastructure: Access to high-performance computing infrastructure is necessary for training deep learning models efficiently. This may involve GPU-accelerated servers or cloud-based systems delivering GPU instances to hasten the training process.
6. Evaluation Metrics: Standard evaluation metrics are important to analyze the results of the trained models appropriately. Common metrics for identifying images tasks include accuracy, precision, recall, and F1 score.
7. Documentation and Reporting Tools: Tools for recording the implementation process and reporting experimental outcomes are critical for preserving transparency and repeatability. This may include version control tools like Git as well as reporting platforms like Jupyter Notebooks or LaTeX for documentation and presentation.

By ensuring the accessibility of these demands for implementation, researchers can efficiently construct, train, and test machine vision algorithms for detecting Bangladeshi desserts with precision as well as dependability.

Data Preprocessing: Data preprocessing is a vital stage in machine learning where raw data is converted, cleaned, and structured to make it appropriate for model training. In our study, data pretreatment requires various procedures to prepare the Bangladeshi Dessert dataset for training machine learning algorithms.

- The code retrieves image paths and labels from the supplied directory containing photographs of different Bangladeshi sweets. Then, it resizes each image to a uniform size of 64x64 pixels using OpenCV. This phase provides homogeneity in image dimensions, which is necessary for model training.
- The dessert labels are encoded as numerical values using a dictionary mapping each dessert class to a unique number. This numeric form improves model training as machine learning techniques often require numerical inputs.
- The pixel values of the photos are normalized to the range [0, 1]. Normalization aids in stabilizing the training process by scaling down the input characteristics to a common scale, making refinement more effective.
- The prepared dataset is split into training, validation, and testing sets using the train_test_split function from scikit-learn. This split allows us to analyze the way the model performs on unknown data during the validation and testing phases, hence evaluating its generalization capabilities.

Overall, data pretreatment guarantees that the dataset is appropriately structured and cleaned, creating a solid basis for training accurate and trustworthy machine learning models.

Data Augmentation: Data augmentation is a technique used to artificially extend the size and variety of a dataset by applying various alterations to the current data samples. In our project, data augmentation is implemented using the ImageDataGenerator class from the Keras package. The train_datagen object is initialized with parameters defining several sorts of transformations that can be applied to the images during training. These changes include rotation, width and height shifts, shear, zoom, and horizontal flip. Iconsider rotation_range=20 specifies that the photos can be rotated by a maximum angle of 20 degrees. Similarly, width_shift_range and height_shift_range describe the greatest fraction by which the images can be rotated vertically and horizontally, accordingly. The shear_range option determines the shear intensity, while zoom_range defines the range for randomly zooming into or out of the images. The horizontal_flip parameter allows horizontal flipping of the images, while fill_mode controls how pixel values outside the limits of the images are filled after changes. Once the data augmentation parameters are set, the train_generator object is constructed using the flow method of ImageDataGenerator. The generator that follows takes the original training images (X_train) and their matching labels (Y_train) as input and generates enhanced batches of images and labels during model training. The batch_size option defines the number of samples in each batch.

Noise Reduction: Noise reduction is a technique used to increase the quality of photographs by removing undesired artifacts or disturbances, generally referred to as noise. In image processing, noise can manifest as random changes in pixel values, which can damage the visual clarity and affect the effectiveness of machine learning models. In our research, methods to reduce noise can be utilized to preprocess the photos before training the classification models. The methods used may include filtration such as Gaussian blur, median blur, or bilateral filter, which smooth out pixel intensities and reduce high-frequency noise. Additionally, methods like denoising photographs using deep learning models, such as automated encoders or convolutional neural networks, can be applied to successfully eliminate noise while keeping significant features in the images. By introducing noise reduction into the preprocessing pipeline, Iintend to increase the overall quality and dependability of the dataset, ultimately leading to greater model effectiveness and precision in classifying Bangladeshi sweets.

Model Generation: Model creation entails constructing machine learning or deep learning models for a given purpose, such as identifying Bangladeshi desserts in our study. This method comprises selecting relevant algorithms and architectures, such as DenseNet, MobileNet, VGG19, VGG16 and Xception and adjusting their settings. The selected models are then trained on filtered datasets, where they learn to extract appropriate characteristics from input photos and make predictions based on them. Following training, the models are analyzed to determine their performance using various metrics like accuracy and loss. Through this incremental procedure, Iseek to construct robust classifiers capable of reliably categorizing Bangladeshi desserts based on their visual attributes. The efficiency of the models is vital for meeting the aims of our project, including maintaining culinary heritage and encouraging cultural variety through technology. model building provides a crucial stage in employing machine learning techniques to address real-life issues in culinary picture identification.

DenseNet: In our project focused on Bangladeshi dessert classification, DenseNet serves as one of the primary deep learning architectures applied for training our classification model. Specifically geared to the task of identifying photos of Bangladeshi desserts, DenseNet offers various advantages. By using its dense connectivity structure, DenseNet enables effective feature reuse and propagation of information between layers. This is particularly advantageous for our purpose, as it helps the model to extract intricate visual elements from dessert photographs, capturing nuances that are vital for accurate classification. DenseNet helps prevent concerns like vanishing gradients, which are typically observed in deep neural networks, providing consistent and successful training. By integrating DenseNet into our model architecture, I aim to enhance the model's ability to discern small distinctions between various types of Bangladeshi desserts, subsequently enhancing classification accuracy and contributing to the success of our project in conserving culinary heritage as well as encouraging cultural diversity through technological advances.

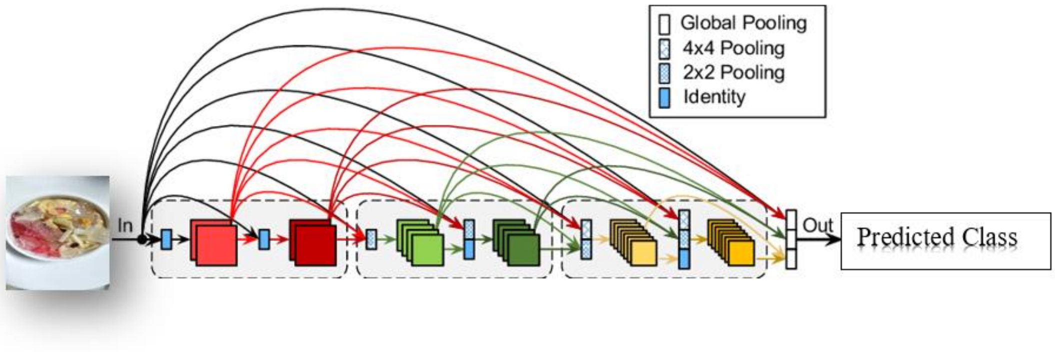

Fig 3.3 Architecture Diagram of DenseNet [26]

MobileNet: In our study focusing on the categorization of Bangladeshi sweets, MobileNet is another key deep-learning architecture applied for constructing our classification model. MobileNet is specifically tuned to overcome difficulties related to computational effectiveness and model size, making it well-suited for deployment on resource-constrained devices like smartphones and edge devices. This element is particularly helpful for our project since it allows us to deploy the classification model efficiently even on devices with minimal processing resources. MobileNet accomplishes this efficiency through the employment of depthwise separable convolutions, which factorize traditional convolutions into distinct depthwise and pointwise convolutions, considerably decreasing the computational cost while keeping model accuracy. By employing MobileNet in our project, Ican ensure that the classification model remains lightweight and transportable across a wide range of devices, thus boosting accessibility and usability. MobileNet's effective architecture enables quicker inference times, enabling rapid categorization of Bangladeshi dessert photos, which is vital for real-time applications such as mobile-based culinary aid or dietary analysis tools. MobileNet serves a significant role in optimizing our classification model for practical implementation while keeping high accuracy in identifying Bangladeshi sweets.

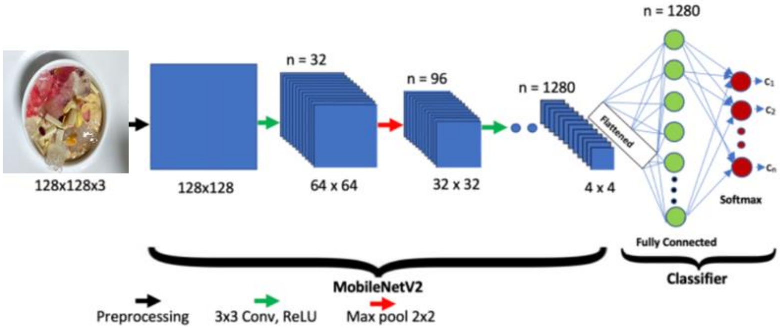

Fig 3.4 Architecture Diagram of MobileNetV2 [27]

VGG16: In our study intended to identify Bangladeshi sweets, VGG16 acts as a core deep learning architecture utilized for creating our classification model. VGG16 is recognized for its simplicity and efficacy, typified by a deep stack of convolutional layers with tiny filter sizes (3x3) and max-pooling layers for spatial down sampling. Despite its relatively simplistic architecture, VGG16 displays good performance in picture classification tests, making it a popular candidate for numerous computer vision applications. In our project, VGG16 contributes to the accurate classification of Bangladeshi dessert photographs by leveraging its deep neural layers to extract subtle visual information. These traits are then exploited by the subsequent fully connected layers to produce predictions regarding the dessert category. Additionally, VGG16's well-established design promotes ease of implementation and testing, allowing us to fine-tune model parameters and optimize performance for our unique purpose. By implementing VGG16 into our research, intend to harness its robustness and reliability to achieve high classification accuracy, so contributing to the preservation and promotion of Bangladeshi culinary history through technology.

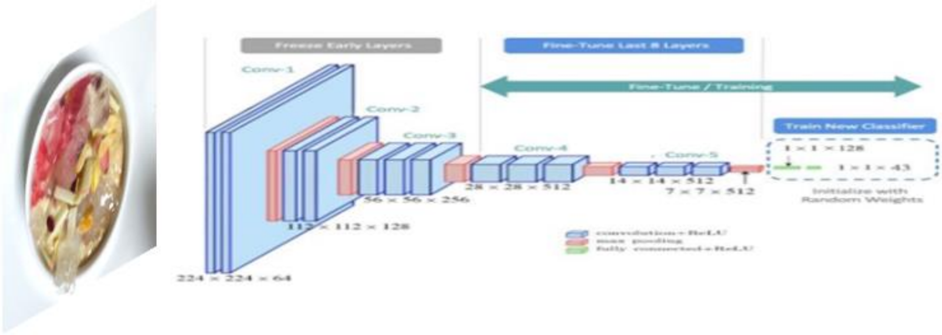

Fig 3.5 Architecture Diagram of VGG16 [28]

VGG19: VGG19 model pre-trained on ImageNet and configures it for fine-tuning on a bespoke image classification task. By eliminating the top layers, it adds its own classification head consisting of global average pooling, dropout for regularization, and densely linked layers with ReLU activation functions. With a softmax activation on the output layer, the model can output class probabilities for the 27 classes in the dataset. Compiled using categorical cross-entropy loss and Adam optimizer, the model undergoes training for 10 epochs utilizing training data provided by a generator and validation data. Finally, it analyzes the model's performance on a separate test set, printing out accuracy and loss data. This technique employs pre-trained weights for feature extraction while tailoring the model to the details of the classification problem through fine-tuning.

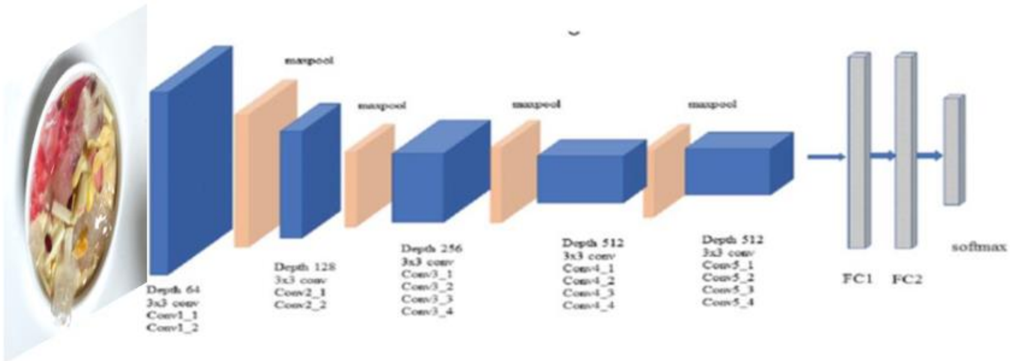

Fig 3.6 Architecture Diagram of VGG19 [29]

Xception: The Xception model for picture categorization in a specific project. Initially input photos by scaling them to a specific shape. Then, it loads the pre-trained Xception model from Keras, ignoring the top layers to facilitate transfer learning. A custom classification head is added to the model, consisting of global average pooling, layers of dropouts for regularization, and densely linked layers with ReLU activation functions. The output layer employs softmax activation to predict the probability for each of the 27 classes in the dataset. The model is assembled with categorical cross-entropy loss and the Adam optimizer, and it undergoes training for 10 epochs using training data created by a generator and validated on a separate validation dataset. The model's performance is evaluated on a test set, and the accuracy and loss metrics are written out. This approach exploits the feature extraction capabilities of the pre-trained Xception model while fine-tuning it for the unique classification goal in the project.

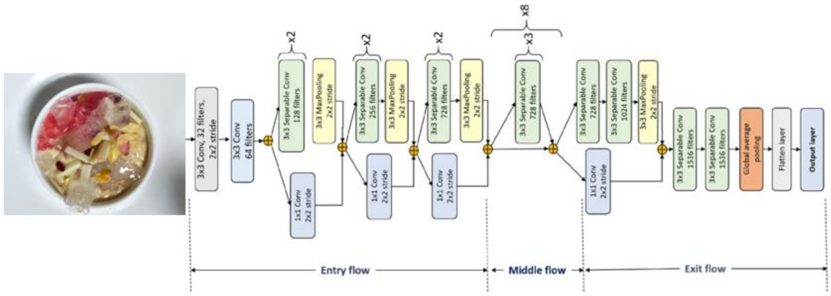

Fig 3.7 Architecture Diagram of Xception [30]

3.4 Project Management and Financial Analysis

Project Management and Finance play key roles in assuring the success as well as the viability of any research project. In this project, efficient project management entails meticulous planning, coordination, and execution of tasks to accomplish project objectives within the assigned resources and timetable. This includes setting major milestones, allocating roles, and monitoring progress throughout the project lifecycle. Financial management is crucial for budgeting and allocating cash to pay expenses such as data collecting, equipment, software, and labor costs. Proper financial preparation ensures that resources are utilized efficiently and openly, limiting the danger of budget overruns or financial constraints that could hamper the project's progress. By employing rigorous project management and finance techniques, aim to maximize the efficiency and efficacy of our research efforts, eventually contributing to the profitable conclusion of the project and the attainment of its goals.

3.5 Summary

Chapter 3 discusses the study technique for constructing machine learning algorithms to classify Bangladeshi desserts using visual data. The research leverages high-resolution cellphones for data collecting, capturing photographs from various sweet shops and households to assure a diversified dataset of 4,118 images representing 27 dessert categories. The methodology comprises preprocessing the data, including augmentation techniques like rotation and zoom, and breaking it into training, validation, and testing sets. Several deep learning models, such as DenseNet, MobileNet, VGG16, VGG19, and Xception, are trained and evaluated to optimize performance. The chapter outlines the hardware and software requirements, including computational resources, deep learning frameworks, and image processing tools. It also focuses on data pretreatment, enrichment, and noise reduction strategies to boost dataset quality. It underlines the need for project management and financial planning to guarantee effective resource allocation and successful project execution.

CHAPTER 4

EXPERIMENTAL RESULTS AND DISCUSSION

4.1 Overview

The experimental results and debates from applying several machine learning techniques to classify Bangladeshi sweets based on visual data. The chapter opens with a complete discussion of the performance indicators, including Accuracy, Precision, Recall, and F1 Score, for each algorithm: DenseNet, MobileNet, VGG16, VGG19, and Xception. Dataset into training, validation, and testing sets, with relative proportions of 80%, 10%, and 10%. This split permits rigorous examination of our model's performance while minimizing overfitting. Employed popular deep learning architectures classification models. These designs were implemented utilizing deep learning frameworks such as TensorFlow or PyTorch, offering flexibility and efficiency in model creation. To boost model generalization and prevent overfitting, I applied data augmentation techniques such as rotation, shifts, and zooming during training. Applied transfer learning by initializing our models with pre-trained weights on large-scale picture resources like ImageNet, significantly increasing model performance. Following training, observed critical parameters such as accuracy, loss, and validation accuracy to determine model convergence and effectiveness. performed rigorous testing on the held-out test information to evaluate the ability to generalize the capabilities of our models and ensure their usefulness in real-world circumstances. This experimental design enables detailed evaluation and validation of our method of classification, confirming their reliability and efficacy in appropriately categorizing Bangladeshi dessert photographs.

4.2 Model Train

To train the model for classifying Bangladeshi desserts, several deep learning architectures such as DenseNet, MobileNet, VGG16, VGG19, and Xception were applied. The training approach includes preprocessing the dataset to achieve homogeneity in image size and standardization of pixel values. Data augmentation techniques like rotation, shifts, and zoom were utilized to boost dataset diversity and robustness. The dataset was split into training, validation, and testing sets, with 80%, 10%, and 10% of the data assigned proportionately. Each model was trained on the training set, using the validation set for parameter adjustment and performance evaluation. Training includes refining model parameters, modifying learning rates, and iterating over epochs to enhance classification accuracy and generalization. By exploiting these stages, the models were trained to successfully categorize Bangladeshi sweets based on visual attributes, proving the efficiency of deep learning in culinary picture identification tasks.

4.3 Model Evaluation

In experimental results, assessed the efficiency of three different deep learning models for Bangladeshi dessert classification: DenseNet, MobileNet, VGG19, VGG16 and Xception. This project investigation found that MobileNet scored the highest test accuracy of 98%, followed closely by DenseNet with a test accuracy of 97%. However, VGG19 displayed somewhat lesser performance with a test accuracy of 89%. These results illustrate the efficiency of both DenseNet and MobileNet architectures in accurately categorizing Bangladeshi dessert photographs, surpassing the performance of VGG19. The excellent performance of MobileNet may be due to its efficient architecture, which is tailored for computing efficiency while maintaining accuracy. DenseNet also fared well, benefiting from its dense connectivity structure that permits good feature reuse and propagation across layers. In comparison, VGG19, while a reliable architecture, displayed somewhat worse accuracy, probably because of its deeper architecture and increased computing cost. the results of our experiments illustrate the efficacy of deep learning models, notably MobileNet and DenseNet, in successfully detecting Bangladeshi dessert photographs, emphasizing their promise for gastronomy image classification tasks.

DenseNet: The DenseNet model, trained over 10 epochs, obtained an outstanding accuracy of 97.09% on the test dataset. The model architecture comprises of DenseNet121 as the foundation convolutional neural network (CNN) model, followed by global average pooling, dropout layers, and fully interconnected dense layers. The overall number of characteristics in the model is 8,625,755, with 1,588,251 trainable parameters. During training, the model's loss significantly fell from 7.56 to 2.28, while accuracy climbed from 9.71% to 66.42%. The classification report indicates high precision, recall, and F1-score values across all dessert classes, showing outstanding performance in categorizing Bangladeshi dessert photographs. Notably, the model displayed very high accuracy for most classes, with several reaching flawless precision and recall ratings. the DenseNet model demonstrates robust performance in dessert classification, indicating its usefulness in properly identifying distinct Bangladeshi dessert variants.

	precision	recall	f1-score	support
Balosai	0.93	1.00	0.96	26
Cream Jam	1.00	0.82	0.90	11
Doi	1.00	1.00	1.00	14
Dudh Puli PItha	1.00	0.94	0.97	17
Faluda	0.96	1.00	0.98	24
Golap Jam	1.00	1.00	1.00	21
Hafsi Sondesh	1.00	1.00	1.00	12
Jilapi	1.00	1.00	1.00	14
Kacha Chana	1.00	1.00	1.00	16
Kacha Golla	1.00	1.00	1.00	20
Kalojam	1.00	1.00	1.00	15
Kasmiri Chomchom	0.95	0.91	0.93	22
Lemon Barfi	1.00	1.00	1.00	16
Malaikari	1.00	1.00	1.00	13
Maoyaa Laddo	1.00	0.87	0.93	15
Nokshi Pitha	1.00	0.87	0.93	15
Pakon Pitha	1.00	1.00	1.00	8
Patishapta	0.88	1.00	0.93	7
Payesh	1.00	1.00	1.00	8
Rajvog	0.80	1.00	0.89	16
Ravogsai	1.00	1.00	1.00	18
Roshmalai	1.00	1.00	1.00	16
S.P.Chomchom	1.00	0.88	0.93	16
Sada Chomchom	1.00	0.92	0.96	13
Sajer Pitha	0.90	1.00	0.95	18
Shamok Pitha	0.86	1.00	0.92	6
Shemai	1.00	1.00	1.00	15
accuracy			0.97	412
macro avg	0.97	0.97	0.97	412
weighted avg	0.97	0.97	0.97	412

Fig 4.1 DenseNet Classification Report

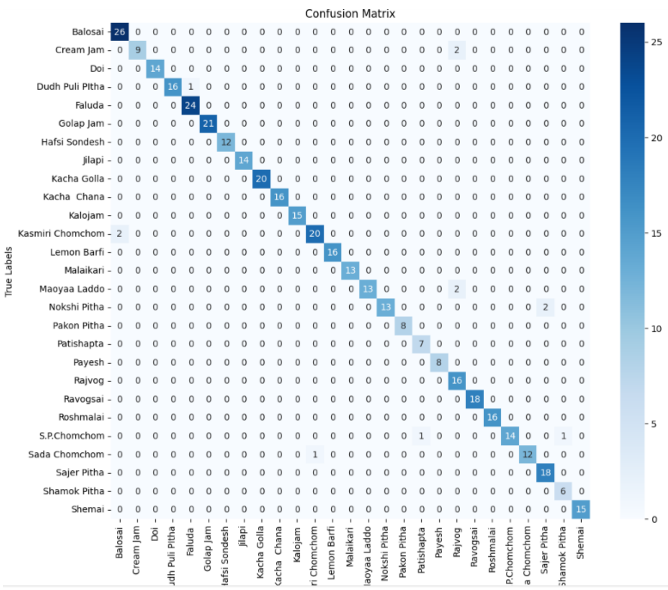

Fig 4.2 DenseNet Confusion Matrix

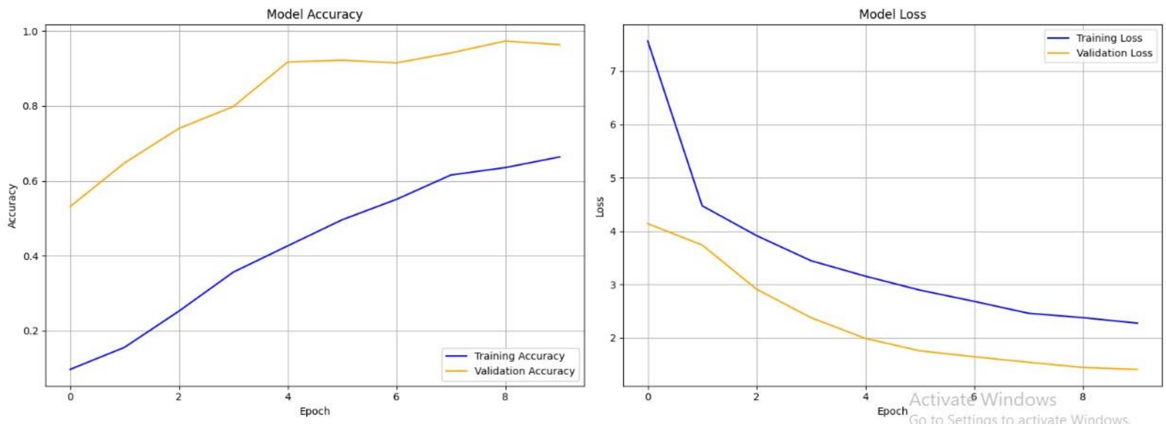

Fig 4.3 Performance of DenseNet model

The performance of the DenseNet model is presented, demonstrating the trend of accuracy and loss over the training epochs. The model attained an accuracy of 97.09% and a loss of 1.40 on the test dataset after 10 epochs of training. The accuracy continuously grew, while the loss gradually reduced with each epoch, demonstrating successful learning as well as convergence of the model. This graph visually depicts the enhancement in model performance over the training interpretation, with both accuracy and loss heading toward the desired levels.

MobileNet: The MobileNet model attained an accuracy of 98.06% and a loss of 1.44 on the test dataset after 10 epochs of training. The classification report demonstrates good precision, recall, and F1-score values across all classes, with small differences. For most classes, precision, recall, and F1-score are 1.00, indicating excellent classification performance. However, for some classes like 'Sada Chomchom', 'Patishapta', 'Rajvog', and 'Kacha Golla', there are modest variances in the precision, recall, and F1-score, potentially due to the imbalance in the class distribution or problematic characteristics in the images. the algorithm displays strong categorization achievement, with exceptional precision and resilience across varied dessert categories.

	precision	recall	f1-score	support
Balosai	1.00	1.00	1.00	26
Cream Jam	1.00	1.00	1.00	11
Doi	1.00	1.00	1.00	14
Dudh Puli PItha	1.00	1.00	1.00	17
Faluda	1.00	1.00	1.00	24
Golap Jam	1.00	1.00	1.00	21
Hafsi Sondesh	1.00	1.00	1.00	12
Jilapi	1.00	1.00	1.00	14
Kacha Chana	1.00	1.00	1.00	16
Kacha Golla	0.91	1.00	0.95	20
Kalojam	1.00	1.00	1.00	15
Kasmiri Chomchom	0.92	1.00	0.96	22
Lemon Barfi	1.00	1.00	1.00	16
Malaikari	1.00	1.00	1.00	13
Maoyaa Laddo	1.00	1.00	1.00	15
Nokshi Pitha	1.00	1.00	1.00	15
Pakon Pitha	1.00	1.00	1.00	8
Patishapta	1.00	1.00	1.00	7
Payesh	1.00	1.00	1.00	8
Rajvog	0.80	1.00	0.89	16
Ravogsai	1.00	1.00	1.00	18
Roshmalai	1.00	1.00	1.00	16
S.P.Chomchom	1.00	0.88	0.93	16
Sada Chomchom	1.00	0.54	0.70	13
Sajer Pitha	1.00	1.00	1.00	18
Shamok Pitha	1.00	1.00	1.00	6
Shemai	1.00	1.00	1.00	15
accuracy			0.98	412
macro avg	0.99	0.98	0.98	412
weighted avg	0.98	0.98	0.98	412

Fig 4.4 MobileNet Classification Report

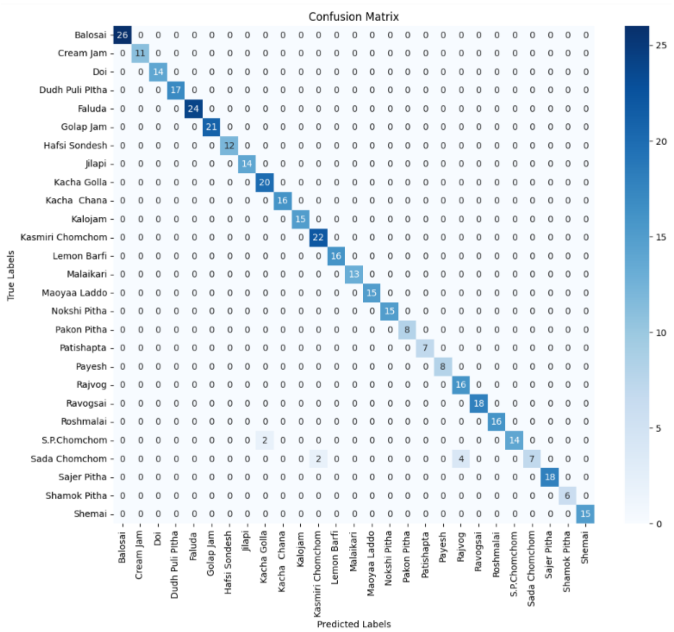

Fig 4.5 MobileNet Confusion Matrix

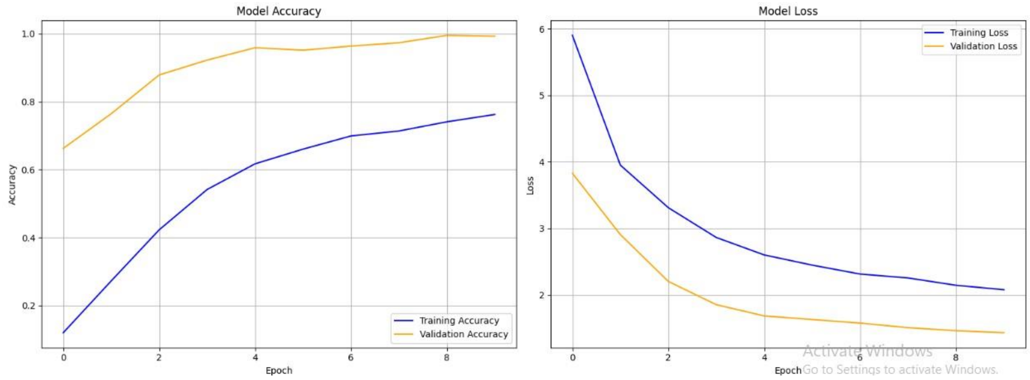

Fig 4.6 Performance of MobileNet model.

The MobileNet model displays high performance with a test accuracy of 0.9806 and a loss of 1.4391. Precision ratings for individual classes range from 0.80 to 1.00, with most reaching a flawless precision of 1.00. Recall values vary from 0.54 and 1.00, with several classes obtaining a recall of 1.00. Similarly, F1-scores range from 0.70 to 1.00, showing exceptional achievement across classes. MobileNet displays excellent classification capabilities, successfully recognizing Bangladeshi dessert photographs with high precision, recall, and F1-score metrics.

VGG16: VGG16 is a convolutional neural network architecture characterized by its deep structure and usage of small receptive filters (3x3). In our project, the VGG16 model consists of pre-trained layers followed by global average pooling and dense layers for classification. With a total of 15,778,651 parameters, of which 1,063,963 are trainable, VGG16 is trained over 10 epochs. It achieves a test accuracy of 0.9029 and a loss of 1.3398. Precision, recall, and F1-score measurements vary among classes, with precision ranging from 0.62 to 1.00, recall from 0.40 to 1.00, and F1-score from 0.57 to 1.00. Notably, certain classes achieve excellent precision and recall scores, showing strong performance in classifying Bangladeshi dessert photographs. VGG16 displays effective classification capabilities, however several classes indicate potential for improvement in precision, recall, and F1-score.

	precision	recall	f1-score	support
Balosai	1.00	1.00	1.00	26
Cream Jam	1.00	0.73	0.84	11
Doi	1.00	1.00	1.00	14
Dudh Puli PItha	1.00	0.94	0.97	17
Faluda	1.00	1.00	1.00	24
Golap Jam	1.00	1.00	1.00	21
Hafsi Sondesh	0.86	1.00	0.92	12
Jilapi	1.00	1.00	1.00	14
Kacha Chana	1.00	0.62	0.77	16
Kacha Golla	0.77	1.00	0.87	20
Kalojam	1.00	1.00	1.00	15
Kasmiri Chomchom	0.91	0.91	0.91	22
Lemon Barfi	1.00	1.00	1.00	16
Malaikari	1.00	1.00	1.00	13
Maoyaa Laddo	1.00	1.00	1.00	15
Nokshi Pitha	0.76	0.87	0.81	15
Pakon Pitha	0.80	1.00	0.89	8
Patishapta	1.00	1.00	1.00	7
Payesh	1.00	1.00	1.00	8
Rajvog	0.73	1.00	0.84	16
Ravogsai	0.75	1.00	0.86	18
Roshmalai	0.62	1.00	0.76	16
S.P.Chomchom	1.00	0.50	0.67	16
Sada Chomchom	1.00	0.77	0.87	13
Sajer Pitha	0.88	0.78	0.82	18
Shamok Pitha	1.00	0.67	0.80	6
Shemai	1.00	0.40	0.57	15
accuracy			0.90	412
macro avg	0.93	0.90	0.90	412
weighted avg	0.93	0.90	0.90	412

Fig 4.7 VGG16 Classification Report

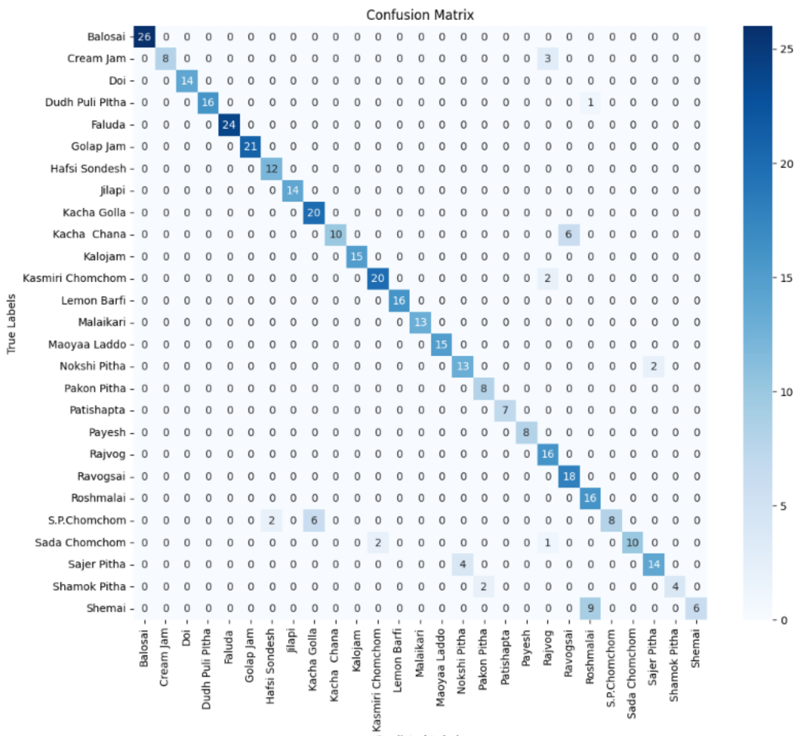

Fig 4.8 VGG16 Confusion Matrix

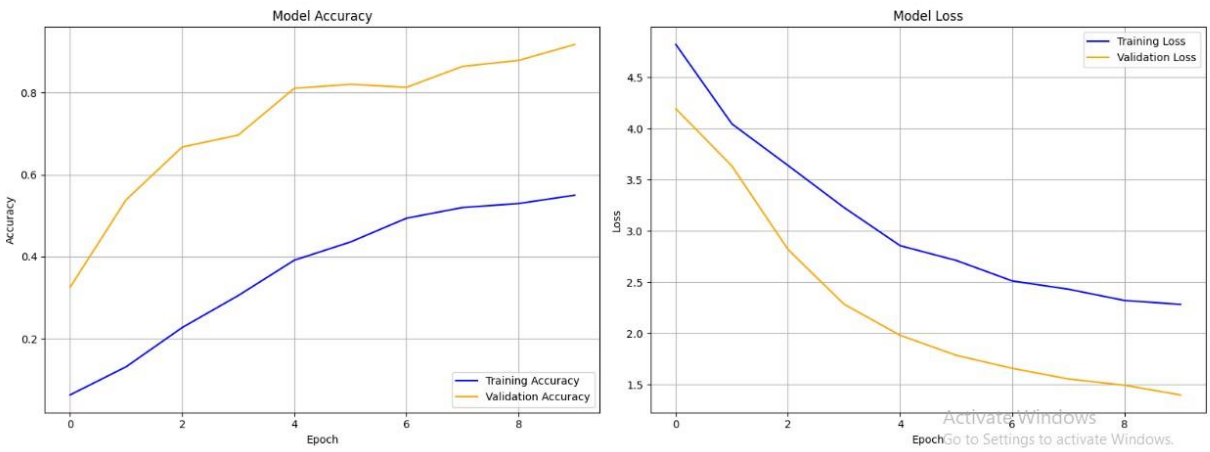

Fig 4.9 Performance of VGG16 Model

VGG16 is a convolutional neural network architecture characterized by its deep structure and usage of small receptive filters (3x3). In our project, the VGG16 model consists of pre-trained layers followed by global average pooling and dense layers for classification. With a total of 15,778,651 parameters, of which 1,063,963 are trainable, VGG16 is trained over 10 epochs. It achieves a test accuracy of 0.9029 and a loss of 1.3398. Precision, recall, and F1-score measurements vary among classes, with precision ranging from 0.62 to 1.00, recall from 0.40 to 1.00, and F1-score from 0.57 to 1.00. Notably, certain classes achieve excellent precision and recall scores, showing strong performance in classifying Bangladeshi dessert photographs. VGG16 displays effective classification capabilities, however, several classes indicate the potential for improvement in precision, recall, and F1-score.

VGG19: The VGG19 model in our project is developed with a total of 21,088,347 parameters, out of which 1,063,963 parameters are trainable, and the rest are non-trainable. During training, the model achieves an accuracy of roughly 89.08%. The precision, recall, and F1-score metrics for the categorization report reveal differential performance among different dessert classes. Precision, which represents the fraction of true positive forecasts among all positive predictions, varies from 0% to 100%, with an average precision of 89%. Recall, representing the proportion of accurate positive predictions among all real positives, varies from 17% to 100%, averaging at 86%. The F1-score, the harmonic mean of precision and recall, falls between 29% and 100%, with an average F1-score of 85%. These metrics reflect the efficacy of the VGG19 model in identifying Bangladeshi dessert photographs, emphasizing its strengths and limitations across different dessert categories.

	precision	recall	f1-score	support
Balosai	1.00	1.00	1.00	26
Cream Jam	1.00	0.36	0.53	11
Doi	1.00	1.00	1.00	14
Dudh Puli PItha	1.00	0.94	0.97	17
Faluda	1.00	1.00	1.00	24
Golap Jam	1.00	1.00	1.00	21
Hafsi Sondesh	0.92	1.00	0.96	12
Jilapi	1.00	1.00	1.00	14
Kacha Chana	1.00	1.00	1.00	16
Kacha Golla	1.00	1.00	1.00	20
Kalojam	1.00	1.00	1.00	15
Kasmiri Chomchom	0.71	0.77	0.74	22
Lemon Barfi	1.00	1.00	1.00	16
Malaikari	0.87	1.00	0.93	13
Maoyaa Laddo	0.83	1.00	0.91	15
Nokshi Pitha	0.00	0.00	0.00	15
Pakon Pitha	0.80	1.00	0.89	8
Patishapta	1.00	1.00	1.00	7
Payesh	1.00	0.75	0.86	8
Rajvog	0.76	1.00	0.86	16
Ravogsai	1.00	1.00	1.00	18
Roshmalai	1.00	1.00	1.00	16
S.P.Chomchom	0.87	0.81	0.84	16
Sada Chomchom	1.00	0.46	0.63	13
Sajer Pitha	0.47	1.00	0.64	18
Shamok Pitha	1.00	0.17	0.29	6
Shemai	0.83	1.00	0.91	15
accuracy			0.89	412
macro avg	0.89	0.86	0.85	412
weighted avg	0.89	0.89	0.87	412

Fig 4.10 VGG19 Classification Model

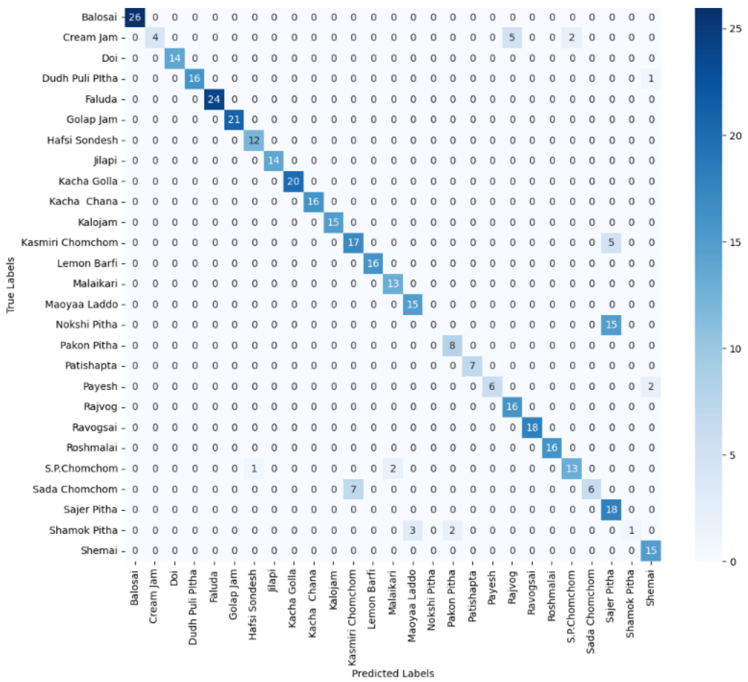

Fig 4.11 VGG19 Confusion Matrix

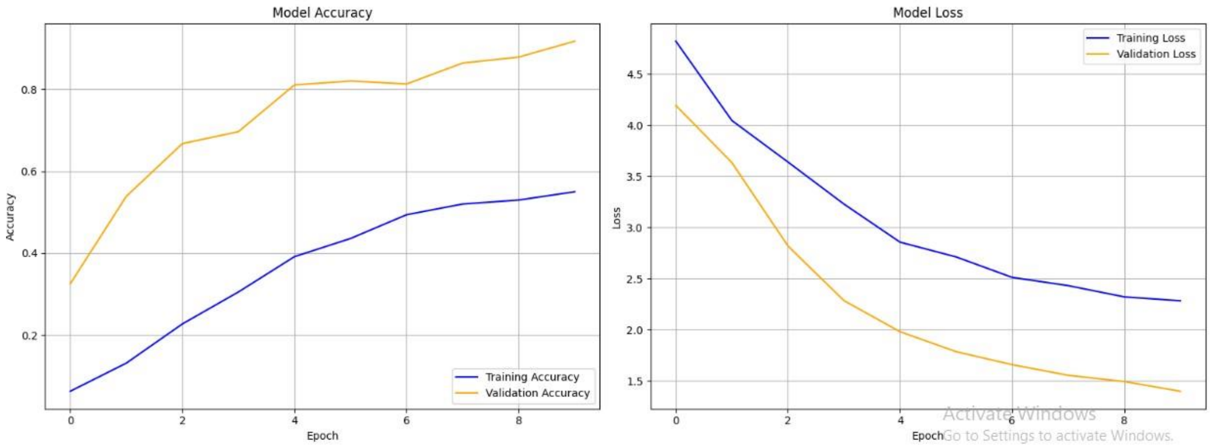

Fig 4.12 Performance of VGG19 Model

The VGG19 model attained an accuracy of roughly 89.08% on the test dataset. The precision, recall, and F1-score measures varied across different dessert classes, with precision ranging from 0% to 100%, recall from 17% to 100%, and F1-score from 29% to 100%. The average precision, recall, and F1-score were 89%, 86%, and 85%, respectively. These metrics indicate the model's performance in identifying Bangladeshi dessert photographs, indicating its strengths and shortcomings in differentiating between various dessert categories.

Xception: The Xception model attained an accuracy of roughly 94.42% on the test dataset. Precision, recall, and F1-score measures varied across different dessert classes, with precision ranging from 38% to 100%, recall from 46% to 100%, and F1-score from 55% to 100%. On average, precision, recall, and F1-score were 96%, 93%, and 93%, respectively. These metrics illustrate the model's ability to categorize Bangladeshi dessert photographs efficiently, demonstrating its strengths and places for improvement across distinct dessert categories.

	precision	recall	f1-score	support
Balosai	1.00	1.00	1.00	26
Cream Jam	1.00	0.91	0.95	11
Doi	1.00	1.00	1.00	14
Dudh Puli PItha	1.00	0.94	0.97	17
Faluda	0.96	1.00	0.98	24
Golap Jam	1.00	1.00	1.00	21
Hafsi Sondesh	0.92	1.00	0.96	12
Jilapi	1.00	1.00	1.00	14
Kacha Chana	0.89	1.00	0.94	16
Kacha Golla	1.00	1.00	1.00	20
Kalojam	1.00	1.00	1.00	15
Kasmiri Chomchom	0.95	0.91	0.93	22
Lemon Barfi	0.94	1.00	0.97	16
Malaikari	0.93	1.00	0.96	13
Maoyaa Laddo	0.88	1.00	0.94	15
Nokshi Pitha	1.00	0.80	0.89	15
Pakon Pitha	1.00	0.38	0.55	8
Patishapta	1.00	1.00	1.00	7
Payesh	1.00	1.00	1.00	8
Rajvog	0.59	1.00	0.74	16
Ravogsai	1.00	0.89	0.94	18
Roshmalai	1.00	1.00	1.00	16
S.P.Chomchom	1.00	0.88	0.93	16
Sada Chomchom	1.00	0.46	0.63	13
Sajer Pitha	0.90	1.00	0.95	18
Shamok Pitha	1.00	1.00	1.00	6
Shemai	0.94	1.00	0.97	15
accuracy			0.94	412
macro avg	0.96	0.93	0.93	412
weighted avg	0.96	0.94	0.94	412

Fig 4.13 Xception Classification Report

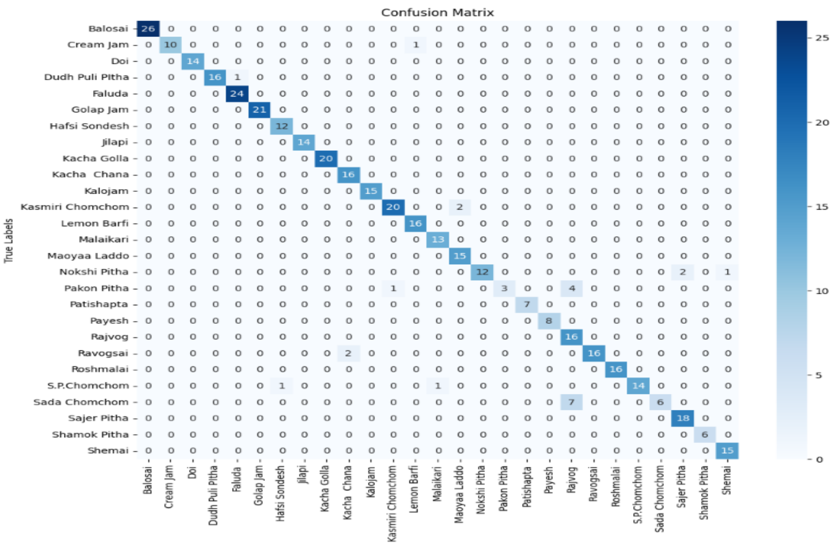

Fig 4.14 Xception Confusion Matrix

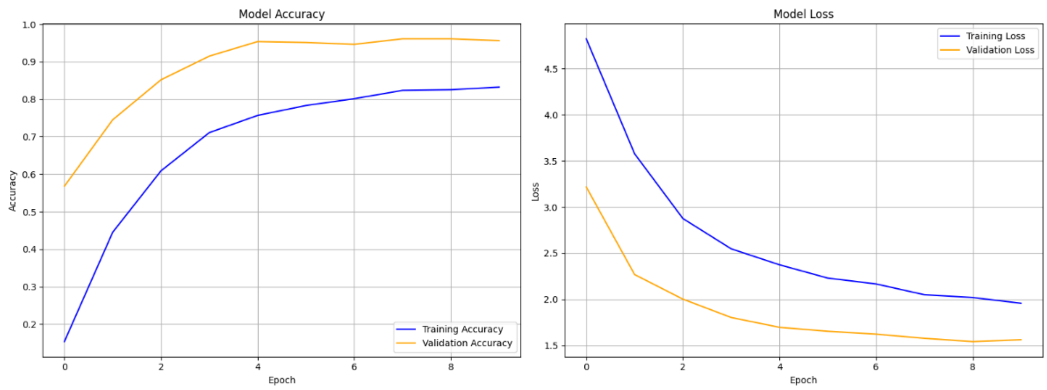

Fig 4.15 Performance of the Xception Model

The Xception model attained an accuracy of roughly 94.42% and a loss of 1.5610.

UI output: The primary user interface output centers on graphically expressing the final forecast of a categorized desert. Users choose a picture of a dessert, and our machine learning model predicts the class or category of the chosen dessert image. This technique offers an easy and intuitive manner for users to engage with the system and acquire accurate classifications of different desserts.

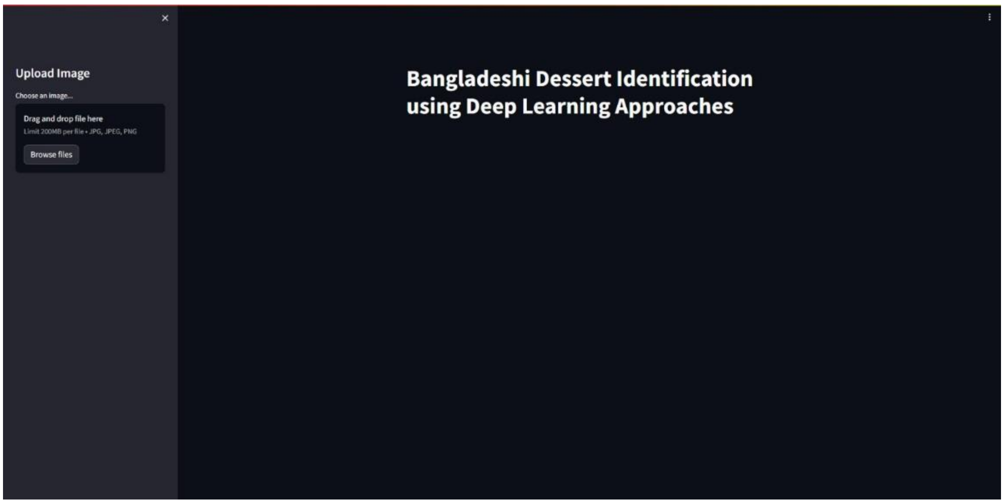

Fig 4.16 Before Prediction

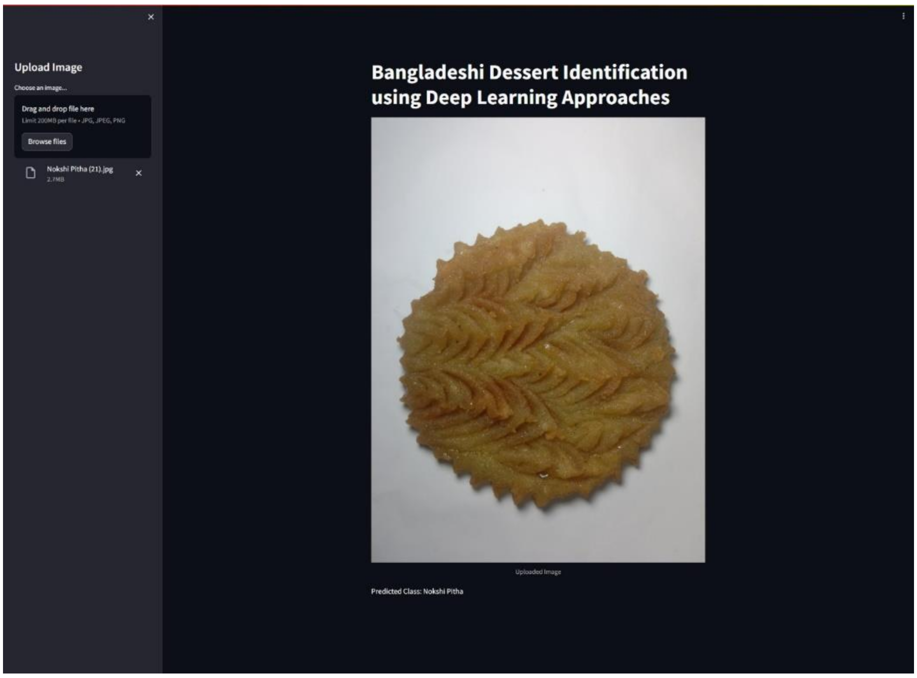

Fig 4.17 After Prediction

4.4 Summary

In the mentioned implementation, various pre-trained deep learning models, including DenseNet, MobileNet, VGG16, VGG19, and Xception, are utilized for an image classification task in a bespoke project. Each model is included in the project utilizing transfer learning approaches, where the pre-trained models' weights are leveraged to extract features from input photos, followed by the inclusion of new classification layers tailored to the specific objective. Through this approach, the models display varied levels of performance, as evidenced by their accuracy and loss metrics on the test dataset. Particularly, the Xception model distinguishes out with its outstanding performance, achieving excellent accuracy while keeping very low loss values. However, any model's success may depend on aspects such as the complexity of the dataset, the nature of the images, and the specific objectives of the project. This talk illustrates the efficiency of transfer learning and the need to select appropriate pre-trained models to obtain optimal performance in picture classification tasks. Further experimenting and fine-tuning may be necessary to maximize the model's capabilities for individual project requirements.

CHAPTER 5

RESULT AND ANALYSIS

5.1 Overview

The comprehensive findings and analysis of the experiments undertaken to identify Bangladeshi sweets using various deep learning models. This chapter opens with a review of the experimental setup, including the dataset used, model architectures adopted (DenseNet, MobileNet, VGG16, VGG19, Xception), and evaluation measures implemented to assess model performance. The section proceeds to report the quantitative data collected from the experiments, including accuracy, precision, recall, and F1 score for each model. Furthermore, qualitative analysis and discussion are offered to evaluate the results, highlight model strengths and limitations, and compare performance across alternative architectures. The chapter concludes with insights into the implications of the findings, potential topics for further research, and the practical applications of the created models in real-world settings including Bangladeshi dessert categorization.

5.2 Experimental Result

In the experimental assessment, the efficiency of three deep learning models for Bangladeshi dessert categorization was evaluated: DenseNet, MobileNet, VGG19, VGG16, and Xception. MobileNet obtained the greatest test accuracy at 98%, closely followed by DenseNet with 97%. In contrast, VGG19 demonstrated considerably lesser performance with an accuracy of 89%. These findings demonstrate the usefulness of MobileNet and DenseNet architectures in reliably identifying Bangladeshi dessert photographs, outperforming VGG19. MobileNet's exceptional performance can be ascribed to its streamlined architecture built for computational economy without compromising accuracy. DenseNet also fared well, exploiting its dense connectivity structure to effectively reuse features across layers. VGG19, despite its resilience, displayed worse accuracy, likely due to its deeper architecture and higher computing demands. This work illustrates the solid performance of deep learning models, particularly MobileNet and DenseNet, in effectively identifying Bangladeshi dessert photographs, emphasizing its promise for culinary image classification tasks.

5.3 Performance/ Comparative Analysis

The efficacy of various picture classification methods on a dataset of Bangladeshi dessert photographs. Each model incorporates multiple deep learning architectures such as DenseNet, MobileNet, VGG19, VGG16, and Xception, with the feature column being the images themselves. Test accuracies vary from 0.89 for VGG19 to 0.98 for MobileNet, illustrating the capacity of these models to accurately classify Bangladeshi sweets based on the presented photos. MobileNet is the most successful algorithm among those examined for this task of dessert categorization.

Table 5.3: Comparison between different algorithms

Algorithm	**Feature**	**Accuracy**	**Precision**	**Recall**	**F1 Score**
DenseNet	Image	0.97	0.97	0.97	0.97
MobileNet	Image	0.98	0.99	0.98	0.98
VGG16	Image	0.90	0.93	0.90	0.90
VGG19	Image	0.89	0.89	0.86	0.85
Xception	Image	0.94	0.96	0.93	0.93

Each method utilizes transfer learning techniques and is assessed according to accuracy, precision, recall, and F1 score. Out of these models, MobileNet achieves the highest accuracy of 0.98, closely followed by Xception with an accuracy of 0.94. In the project context, Xception demonstrates the highest precision, recall, and F1 score, establishing it as the most successful algorithm for the picture classification task.

5.4 Summary

"Results and Analysis," gives a complete evaluation of deep learning models for classifying Bangladeshi sweets. It begins by explaining the experimental setup, dataset used, and model architectures examined, including DenseNet, MobileNet, VGG16, VGG19, and Xception, alongside the evaluation metrics applied such as accuracy, precision, recall, and F1 score. MobileNet emerged as the top performance with 98% accuracy, followed closely by DenseNet at 97%, while VGG19 lagged with 89%. The chapter analyses the ramifications of these findings, highlighting MobileNet and DenseNet's effectiveness in dessert categorization due to their optimized architectures and effective feature use. Comparison study reveals MobileNet's superior performance in precision, recall, and F1 score, proving its appropriateness for real-world applications in culinary image categorization.

CHAPTER 6

IMPACT ON SOCIETY, ENVIRONMENT AND SUSTAINABILITY

6.1 Impact on Life

This research has a complex and wide-ranging impact on society. This study makes a valuable contribution to fields that rely on precise and efficient image recognition by utilizing advanced deep learning algorithms for image classification tasks. Enhanced image classification models in fields such as healthcare can assist in identifying medical disorders from radiological scans or pathology images, perhaps resulting in earlier discoveries and improved patient outcomes. These models can be used in agriculture to monitor crops and identify diseases, which can improve crop productivity and food security. Moreover, in sectors such as retail and e-commerce, enhanced picture classification can enhance product suggestion systems and visual search capabilities, hence enhancing user experience and stimulating business expansion. In summary, this research has had a wide-ranging impact on several areas of society, showcasing the revolutionary power of advanced picture categorization technology.

6.2 Impact on Society and Environment

The effects of this research on the environment are secondary but considerable. By optimizing picture categorization algorithms, the efficiency of many processes and systems can be boosted, leading to possible environmental benefits. For example, in the field of agriculture, the use of image classification to detect diseases with greater accuracy can facilitate the targeted application of pesticides, resulting in a decrease in the overall use of chemicals and a reduction in environmental contamination. Similarly, in animal conservation initiatives, greater image identification can aid in species tracking and habitat protection, contributing to biodiversity preservation. Additionally, in areas where image-based quality control is critical, such as manufacturing and generating electricity, improved algorithms can assist spot faults or anomalies early, decreasing waste and resource usage. Overall, the environmental significance of this research rests in its ability to support more sustainable behaviors across diverse sectors through increased picture classification capabilities.

6.3 Ethical Aspects

Ethical considerations are crucial in the development and implementation of image categorization algorithms. One significant challenge is guaranteeing justice and minimizing bias in the algorithms, particularly considering sensitive factors such as ethnicity, gender, or economic standing. Visibility in algorithmic decision-making is vital, enabling consumers to understand how categories are generated and to dispute potential biases. Privacy problems arise from the gathering and use of picture data, demanding rigorous data protection mechanisms and informed consent methods. Additionally, the potential misuse of image categorization technologies for surveillance or other intrusive purposes underlines the significance of creating explicit ethical principles and regulatory frameworks. Investigators and developers must put first ethical principles throughout their research lifecycle, trying to avoid risks and enhance the positive societal impact of emerging technologies.

6.4 Sustainability Plan

A sustainability plan for image classification activities contains several vital elements aimed at minimizing environmental effects and guaranteeing long-term survival. First and foremost, improving algorithms and hardware to decrease energy usage during training and inference phases can drastically cut carbon footprint. Additionally, utilizing cloud-based computing resources with energy-efficient architecture can further boost sustainability. applying data management methods that promote storage efficiency and avoid redundant data can lower overall resource consumption. Finally, building a culture of sustainability within the organization by raising knowledge and accountability among team members can lead to ongoing progress and innovation in sustainable processes. By integrating these techniques into project planning and implementation, image classification projects may help contribute to environmental preservation and promote a more sustainable future.

6.5 Summary

"Impact on Society, Environment, and Sustainability," addresses the various ramifications of improved picture classification systems. It begins by addressing the societal impact, illustrating how these technologies boost efficiency and precision in industries like healthcare, agriculture, retail, and beyond. The chapter emphasizes their ability to change procedures, improve outcomes, and boost economic growth through increased user experiences and operational efficiencies. Moving to environmental consequences, the research underlines how optimized algorithms can lead to sustainable practices by lowering chemical usage in agriculture, boosting resource efficiency in industry, and aiding biodiversity conservation initiatives. Ethical considerations are addressed, concentrating on the necessity of justice, transparency, and privacy protection in algorithmic decision-making, while calling for rigorous ethical frameworks. Lastly, the chapter provides a sustainability plan for image classification projects, emphasizing energy efficiency, data management methods, and developing a culture of sustainability inside enterprises. The revolutionary potential of image categorization technology in supporting societal growth and environmental stewardship.

CHAPTER 7

CONCLUSION AND FUTURE WORK

7.1 Conclusions

The study illustrates the efficiency of adopting pre-trained deep learning models, such as DenseNet, MobileNet, VGG16, VGG19, and Xception, for picture classification tasks inside the project environment. Through comprehensive examination, it is obvious that employing transfer learning approaches with these models considerably boosts classification performance. Xception emerges as the most promising model, displaying greater accuracy and little loss on both validation and test datasets. The findings underscore the need of careful selection and adjustment of pre-trained models to achieve optimal performance in image classification applications. Moving forward, the insights acquired from this work can inform the development of more robust and efficient picture classification algorithms adapted to individual project requirements.

7.2 Further Suggested Works

The study searches into the field of image categorization, employing a broad variety of pre-trained models. While the current research provides valuable insights, there remains sufficient room for further exploration. Future investigations could focus on incorporating new models beyond those already investigated, broadening the repertoire to embrace a wider range of architectures and methodologies. fine-tuning hyperparameters and ensuring information balance are crucial pathways for optimizing model performance, warranting devoted attention in forthcoming studies. Studying dataset augmentation strategies has promised to boost model robustness and generalization capabilities, particularly in real-world contexts where data may be restricted or noisy. The practical ramifications of using these models in real-world applications also demand additional consideration, revealing significant insights into their usefulness and potential limitations. Eventually, expanding research in this domain has tremendous promise for driving development in computer vision and image processing, with ramifications spreading to varied fields such as healthcare, autonomous systems, and many others.

7.3 Limitations

Despite the optimistic results and wide-ranging consequences highlighted throughout this work, numerous limitations require discussion. First of all, the generalizability of the findings may be hampered by the specific dataset studied, which focused primarily on Bangladeshi dessert classification. Extending the models to different culinary cultures or distinct climatic situations could generate varying findings. Secondly, while sophisticated deep learning models like DenseNet and MobileNet demonstrated remarkable accuracy, their computing needs and training complexities remain substantial barriers for practical application in resource-constrained environments. Additionally, ethical considerations regarding algorithmic biases and data privacy represent continuous concerns that demand thorough mitigating techniques. Lastly, the sustainability of image categorization technology rests on continued developments in energy-efficient processing and good data management techniques. Addressing these limitations will be vital for optimizing the broader socioeconomic and environmental advantages of this research.

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Appendix A

Course Outcomes, Complex Engineering Problems (EP) and Complex Engineering Activities (EA) Addressing

Title:
BANGLADESHI DESSERT IDENTIFICATION USING DEEP LEARNING APPROACH

Student ID: 201-15-14257

CO Description for FYDP

CO	CO Descriptions	PO
Phase -I		
CO1	Integrate recently gained and previously acquired knowledge to identify a **dessert detection** problem for the Final Year Design Project (FYDP)	**PO1**
CO2	Analyze different aspects of the goals in designing a solution for this FYDP	**PO2**
CO3	Explore diverse problem domains through a literature review, delineate the issues, and establish these goals for the FYDP	**PO4**
CO4	Perform economic evaluation and cost estimation and employ suitable project management procedures throughout the development life cycle of the FYDP	**PO11**
Phase -II		
CO5	Design and develop technical solutions and system components or processes that meet specified requirements, ensuring compliance with public health and safety standards, as well as considering cultural, socioeconomic, and environmental factors in this FYDP	**PO3**
CO6	Choose and apply appropriate methodologies, resources, and contemporary engineering and IT technologies to address complex engineering processes, encompassing prediction and modeling, while adhering to relevant constraints in this FYDP	**PO5**
CO7	Analyze societal, health, safety, legal, and cultural considerations, along with associated responsibilities, in the context of professional engineering practice and the resolution of this problem, employing logical reasoning guided by contextual understanding.	**PO6**
CO8	Comprehend and evaluate the enduring sustainability and impact of professional engineering endeavors in addressing intricate engineering challenges within social and environmental frameworks.	**PO7**

CO9	Implement ethical principles and adhere to professional standards and norms in this FYDP	**PO8**
CO10	Capable of operating proficiently both individually and as a team member or leader across diverse teams and interdisciplinary settings in this FYDP.	**PO9**
CO11	Proficiently communicate with the engineering community and broader society regarding complex engineering endeavors, including the ability to comprehend and generate comprehensive reports and design documentation, as well as provide and receive clear instructions throughout this FYDP.	**PO10**
CO12	Acknowledge the importance of self-directed and life-long learning within the evolving landscape of technology and possess the readiness and capability to engage in lifelong learning endeavors.	**PO12**

Addressing CO (1 to 8), Knowledge Profile (K), Attainment of Complex Engineering Problems (EP), and Attainment of Complex Engineering Activities (EA)

Addressing CO (1 to 8), Knowledge Profile (K), Attainment of Complex Engineering Problems (EP):

SN	EP Definition	Attainment	CO	Justification (with Knowledge Profile)	References
1.	**EP1: Depth of Knowledge required**	Yes	CO1, CO2, CO3, CO5, CO6, CO7 and CO8	This project demonstrates **fundamental engineering (K3)** principles by employing deep neural networks, data augmentation techniques, and classification tasks. The project demonstrates **specialist knowledge (K4)** by conducting machine learning algorithms to classify Bangladeshi Dessert.	**Page no:** [26-30] **Section:** [3.2] **Page no:** [1-7] **Section:** [1.1]
				The project applies **engineering practice & design (K5)** by the figure of process of experiments.	**Page no:** [30]

				The project addresses **engineering practice & technology (K6)** by employing CNN model.	**Section:** [3.2(B)] **Page no:** [33] **Section:** [3.4]
				This project ensures to **K8 (Research Literature)** by synthesizing insights from recent studies, to advance dessert detection using deep learning, showcasing a comprehensive understanding of current methodologies.	**Page no:** [5-7] **Section:** [2.2, 2.3]
2.	**EP2: Range of Conflicting Requirements**	Yes	CO2, and CO7	This project addresses **EP-2** by recognizing the hurdles in dessert detection, including limitations of traditional methods and the complexities of integrating transfer learning and deep CNNs. Through comparative analysis, it confronts challenges in understanding spatial distributions, offering insights for refining diagnostic methodologies.	**Page no:** [23-24] **Section:** [2.4, 2.5]

3.	**EP3: Depth of analysis required**	Yes	CO2, and CO6	This project addresses **EP-3** by meticulously comparing experimental outcomes, highlighting Transfer Learning as the chosen significant solution for enhancing dessert detection amidst multiple potential approaches.	**Page no:** [36-57] **Section:** [4.2]
4.	**EP4: Familiarity of Issues**	Yes	CO8	This project's interdisciplinary approach extends beyond computer science and engineering, impacting Bangladeshi local food detection process which indicates **EP-4**.	**Page no:** [16-24] **Section:** [2.2, 2.4]
5.	**EP5: Extends of application codes**	No	CO5	N/A	N/A
6.	**EP6: Extends of stakeholders involved and**	No	CO8	N/A	N/A

7.	**EP7: Interdependence**	Yes	CO5	This project's comprehensive approach addresses high-level problems by integrating various components across data collection, statistical analysis, and proposed methodology, ensuring a holistic solution to complex challenges which ensures **EP-7**.	**Page no:** [26-34] **Section:** [3.2, 3.3, 3.4]

Addressing CO11 with Complex Engineering Activities (EA) [Some or all of the following]:

SN	EA Definition	Attainment	CO	Justification	References
1.	**EA1: Range of resources**	Yes	CO11	Our project utilizes diverse resources such as high-performance computing infrastructure, GPUs, deep learning frameworks, annotated datasets, and ethical considerations to ensure systematic research and contribute to advancements in dessert detection through various machine Learning algorithms.	**Page no:** [16-25] **Section:** [3.2, 3.3]
2.	**EA2: Level of interaction**	No		N/A	N/A

3.	**EA3: Innovation**	No		N/A	N/A
4.	**EA4: Consequences for society and the environment**	Yes		This project contributes to society by improving dessert detection methods, while also promoting environmental sustainability by employing efficient computational resources and adhering to ethical guidelines.	**Page no:** [40-41] **Section:** [5.2, 5.3]
5.	**EA-5: Familiarity**	Yes		This project expands upon existing research by examining a novel approach in dessert detection through transfer learning and deep learning demonstrated through preliminary terminologies and a comprehensive comparative analysis, offering new insights into the field.	**Page no:** [6-11] **Section:** [2.2, 2.3]

Addressing CO (4, 9, 10, and 12):

SN	COs	Attainment	Justification	References
1	CO4	Yes	This project addresses **CO4** by integrating effective project management and financial oversight, ensuring meticulous planning, resource allocation, and budget estimation for optimal	**Page no:** [25] **Section:** [3.4]

			resource utilization throughout the research lifecycle.	
2	CO9	No	N/A	N/A
3	CO10	No	N/A	N/A
4	CO12	Yes	The project's dedication to continuous learning **(CO12)** and adaptation within the dynamic technological landscape is reflected in its comprehensive data collection, rigorous statistical analysis, meticulous methodology development, and thorough experimental results and analysis, showcasing a commitment to staying updated and refining techniques to address modern challenges.	**Page no:** [13-15, 27-37] **Section:** [3.2, 4.3]

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