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End-of-studies project

On the topic:

**Development of a Classification System for
Skin Lesions in Dermoscopic Images Using AI**

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Abstract

In the field of dermatological imaging, the accurate classification of skin lesions is a critical task that significantly impacts early diagnosis and treatment planning for skin cancer. This report presents a comprehensive exploration of deep learning techniques, specifically focusing on the application of the YOLOv8 framework for skin lesion classification using dermoscopic images. By leveraging the real-time processing capabilities of the YOLO architecture and advanced class-balancing techniques, this work achieves high levels of accuracy in classifying melanoma, basal cell carcinoma (BCC), benign keratosis (BK), and benign nevus.

The proposed model was assessed using standard evaluation metrics including accuracy, precision, recall, and F1-score, demonstrating exceptional performance with 93.35% overall accuracy and class-specific F1-scores up to 0.97 for melanoma classification. Implemented as a standalone desktop application using Tkinter, it provides dermatologists with an intuitive graphical interface for local image analysis without requiring internet connectivity or cloud dependencies. This offline capability ensures patient data privacy compliance while enabling efficient lesion classification in resource-limited settings.

This research contributes to the growing field of AI-assisted dermatology while highlighting YOLO's potential to revolutionize skin cancer diagnostics through efficient, scalable solutions. Future directions for this work include the expansion of the dataset, enhancing the Tkinter GUI for clinical use, and the integration of skin lesion segmentation capabilities to further improve diagnostic accuracy.

Résumé

Dans le domaine de l'imagerie dermatologique, la classification précise des lésions cutanées est une tâche cruciale qui impacte significativement le diagnostic précoce et la planification du traitement du cancer de la peau. Ce rapport présente une exploration approfondie des techniques d'apprentissage profond, en se concentrant spécifiquement sur l'application du cadre YOLOv8 pour la classification des lésions cutanées à l'aide d'images dermoscopiques. En tirant parti des capacités de traitement en temps réel de l'architecture YOLO et des techniques avancées d'équilibrage des classes, ce travail atteint des niveaux élevés de précision dans la classification du mélanome, du carcinome basocellulaire (BCC), de la kératose bénigne (BK) et du nævus bénin.

Le modèle proposé a été évalué à l'aide de métriques standards incluant l'exactitude, la précision, le rappel et le F1-score, démontrant des performances exceptionnelles avec une exactitude globale de 93,35% et des F1-scores atteignant 0,97 pour la classification du mélanome. Implémenté sous forme d'application desktop autonome utilisant Tkinter, il fournit aux dermatologues une interface graphique intuitive pour l'analyse locale d'images sans nécessiter de connectivité internet ni dépendances cloud. Cette capacité hors-ligne garantit la conformité aux réglementations sur la confidentialité des données médicales tout en permettant une classification efficace des lésions dans des environnements à ressources limitées.

Cette recherche contribue au domaine croissant de la dermatologie assistée par l'IA, tout en soulignant le potentiel de YOLO à révolutionner le diagnostic du cancer de la peau grâce à des solutions efficaces et évolutives. Les perspectives futures de ce travail incluent l'élargissement du jeu de données, l'amélioration de l'interface Tkinter pour un usage clinique et l'intégration de fonctionnalités de segmentation des lésions cutanées afin d'améliorer encore la précision diagnostique.

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List of Abbreviations

FSM	Faculté des Sciences Meknès
AI	Artificial Intelligence
ML	Machine Learning
DL	Deep Learning
BCC	Basal Cell Carcinoma
BK	Benign Keratosis
CNN	Convolutional Neural Network
CV	Computer Vision
GUI	Graphical User Interface
GPU	Graphics Processing Unit
ISIC	International Skin Imaging Collaboration
SMI	Sciences Mathématiques et Informatique
YOLO	You Only Look Once
MRI	Magnetic Resonance Imaging
ABCD	Asymmetry, Border, Color, Diameter
SVM	Support Vector Machine
ViT	Vision Transformer
PSNR	Peak Signal-to-Noise Ratio
C2f	Coarse-to-Fine
ISBI	International Symposium on Biomedical Imaging
HAM	Human Against Machine
VGG16	Visual Geometry Group 16
R-CNN	Region-based Convolutional Neural Network
ONNX	Open Neural Network Exchange
TensorRT	NVIDIA TensorRT
fliplr	Flip Left-Right
hsv	Hue, Saturation, Value
avg	Average

General Introduction

1.1 Context

Skin cancer is one of the most prevalent forms of cancer worldwide, accounting for a significant number of cancer diagnoses annually. Among its various types, melanoma poses the highest threat due to its aggressive nature and high mortality rate if not detected early. Early and accurate diagnosis of skin lesions, particularly melanoma, is vital to improving patient outcomes and survival rates. Dermoscopic imaging, a non-invasive technique that magnifies skin structures, has become a cornerstone in dermatology for identifying and classifying skin lesions. However, interpreting dermoscopic images can be challenging, often requiring extensive expertise and training, which makes the process susceptible to human error [Esteva17].

The emergence of artificial intelligence (AI) has revolutionized numerous fields, including healthcare. AI-powered systems, particularly those based on deep learning, have demonstrated remarkable accuracy and efficiency in medical image analysis. In the domain of skin lesion classification, AI provides an opportunity to bridge the gap in expertise, especially in underserved regions where access to skilled dermatologists is limited. Studies have shown that AI systems not only enhance diagnostic accuracy but also deliver results faster than traditional methods, making them ideal for time-sensitive scenarios [Pham21]. By automating the analysis of dermoscopic images, these systems can play a critical role in early detection and intervention, which are crucial for improving survival rates in melanoma cases [Liu24].

1.2 Problem Statement

Despite advancements in dermoscopic imaging and AI, developing a reliable classification system for skin lesions remains a challenging endeavor. Medical image classification poses unique difficulties, such as:

1. Variability in lesion appearance due to differences in color, texture, and shape.
2. The imbalance in datasets, where certain lesion types are underrepresented, leading to biased models.
3. The need for high accuracy and specificity to minimize false positives and negatives, as misdiagnoses can have severe consequences.
4. Integration challenges requiring interpretability and trustworthiness.

These challenges underscore the need for robust AI systems capable of handling dermoscopic image nuances[Tschandl18][Haenssle18].

1.3 Objectives

The primary objectives of this project are:

1. **Develop a YOLOv8-Based Classification System** To design and implement a classification system for dermoscopic images using YOLOv8, leveraging its state-of-the-art performance to identify and categorize various skin lesion types effectively [Ultralytics23].
2. **Optimize Model Selection and Performance** To evaluate and compare the performance of YOLOv8 model variants (n, m, x) based on metrics such as accuracy, specificity, and generalizability, identifying the optimal variant for the classification task [Howard20].
3. **Address Dataset Challenges** To mitigate challenges such as class imbalance and variability in lesion appearance by applying advanced preprocessing techniques, data augmentation, and model fine-tuning for enhanced classification results [Litjens17].
4. **Document Challenges and Recommendations** To document the development process, highlight the challenges encountered, and provide actionable recommendations for improving YOLOv8-based classification systems in medical imaging [Tschandl18].

1.4 Structure of the Report

This report is organized as follows:

- **Chapter 1: General Introduction**

Presents the clinical and technical context, defines the problem, outlines objectives, and explains the report structure.

- **Chapter 2: Deep Learning Overview**

Reviews deep learning fundamentals, computer vision, classification metrics, and their application to medical imaging and skin cancer.

- **Chapter 3: State of the Art**

Surveys recent advances in skin lesion classification, including traditional and deep learning approaches, with a focus on frameworks like MelaNet.

- **Chapter 4: Proposed Solution: YOLOv8**

Details the YOLOv8 architecture, dataset preparation, training process, evaluation metrics, results, and the development of a desktop GUI application.

- **Chapter 5: Discussion**

Discusses the strengths, limitations, and lessons learned from the project, and provides insights for future improvements.

- **Chapter 6: Conclusion**

Summarizes the achievements, significance, and future perspectives of the project.

- **Bibliography**

Lists all references cited throughout the report.

Deep Learning Overview

2.1 Definition

Deep learning (DL) is a subfield of machine learning that employs artificial neural networks with multiple layers (deep architectures) to model complex patterns in data. Unlike traditional machine learning, which relies on manual feature engineering, DL automates feature extraction through hierarchical learning, enabling it to excel in tasks like image recognition, natural language processing, and decision-making [Goodfellow16]. Its significance lies in its ability to process unstructured data (e.g., images, text) at scale, driving breakthroughs in autonomous systems, healthcare diagnostics, and personalized recommendations [LeCun15].

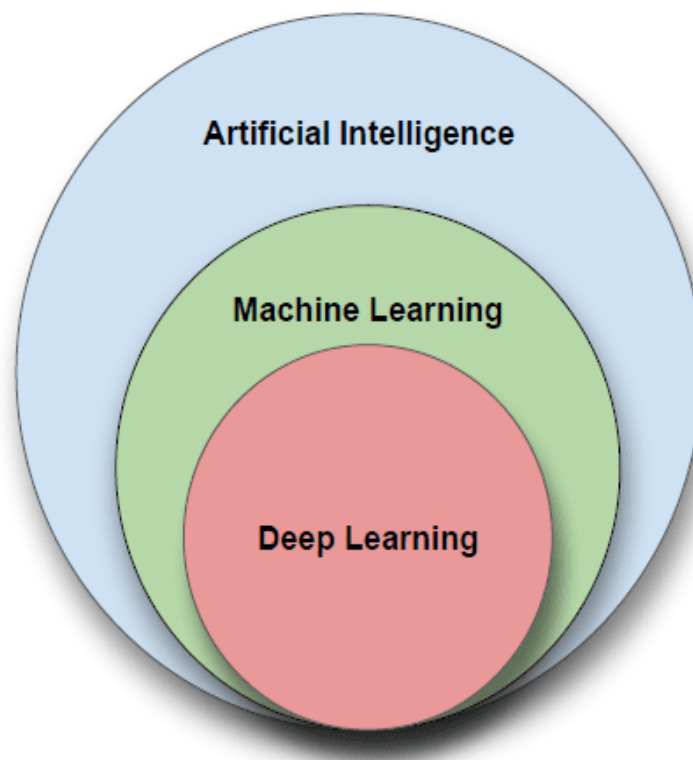


Figure 2.1: Deep Learning Overview

2.2 Computer Vision in Deep Learning

Computer vision (CV) is a field of artificial intelligence that enables computers to interpret and understand visual information from the world, such as images and videos. Deep learning has revolutionized CV by providing powerful tools for automatic feature extraction and pattern recognition, eliminating the need for manual feature engineering.

A cornerstone of deep learning in computer vision is the Convolutional Neural Network (CNN), which uses layers of convolutional filters to learn spatial hierarchies of features directly from pixel data [Ronneberger15]. CNNs are highly effective at capturing local and global patterns, making them the foundation for most modern CV applications.

Key applications of deep learning in computer vision include:

- **Image Classification:** Assigning a label to an entire image, such as distinguishing between benign and malignant skin lesions.
- **Object Detection:** Identifying and localizing multiple objects within an image, for example, detecting tumors or lesions in medical scans.
- **Semantic Segmentation:** Assigning a class label to each pixel in an image, enabling precise delineation of structures like tumor boundaries [Ronneberger15b].
- **Instance Segmentation:** Differentiating between individual objects of the same class within an image, which is crucial for counting and analyzing multiple lesions.

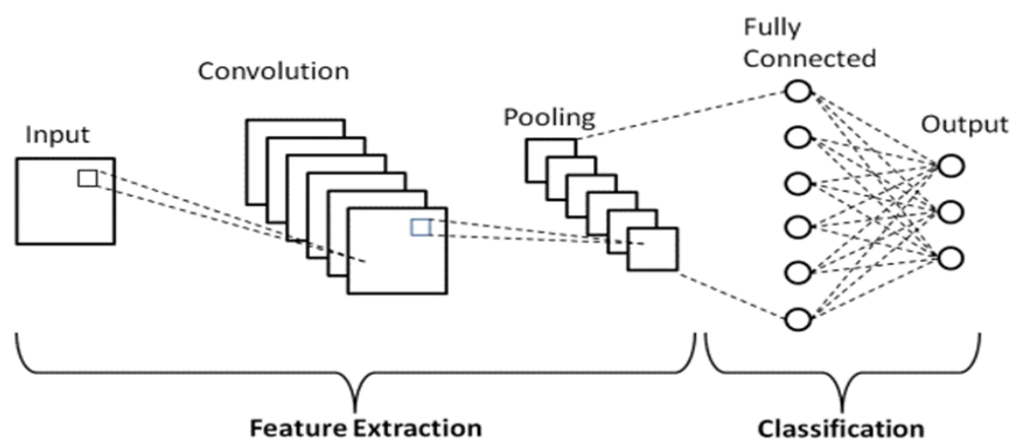


Figure 2.2: Convolutional Neural Network for Computer Vision

In medical imaging, these techniques have enabled automated analysis of X-rays, MRIs, and dermoscopic images, improving diagnostic accuracy and efficiency [Esteva17b]. Deep learning models can detect subtle patterns that may be missed by human observers, assist in early disease detection, and support clinical decision-making.

2.3 Classification

Classification is the process of assigning input data to one of several predefined categories or classes. In deep learning, this is typically accomplished using neural networks with a softmax activation function in the final layer, which outputs a probability distribution over the possible classes.

In medical imaging projects such as skin cancer diagnosis, classification tasks are essential for:

- **Binary Classification:** Distinguishing between two classes, such as malignant vs. benign lesions.
- **Multi-Class Classification:** Identifying specific subtypes of skin cancer (e.g., melanoma, basal cell carcinoma, benign keratosis, nevus) [He16].

Performance Metrics

To evaluate the effectiveness of classification models, several performance metrics are commonly used:

- **Accuracy:** The proportion of correctly classified samples among all samples.

$$\text{Accuracy} = \frac{TP + TN}{TP + TN + FP + FN}$$

- **Sensitivity (Recall or True Positive Rate):** The proportion of actual positives correctly identified.

$$\text{Sensitivity} = \frac{TP}{TP + FN}$$

- **Specificity (True Negative Rate):** The proportion of actual negatives correctly

identified.

$$\text{Specificity} = \frac{TN}{TN + FP}$$

- **Precision (Positive Predictive Value):** The proportion of positive predictions that are correct.

$$\text{Precision} = \frac{TP}{TP + FP}$$

- **F1-score:** The harmonic mean of precision and recall, providing a balance between the two.

$$\text{F1-score} = 2 \times \frac{\text{Precision} \times \text{Recall}}{\text{Precision} + \text{Recall}}$$

Where:

- TP = True Positives
- TN = True Negatives
- FP = False Positives
- FN = False Negatives

These metrics provide a comprehensive assessment of model performance, especially in medical contexts where both false positives and false negatives can have significant consequences [Litjens17].

2.4 Deep Learning in Medicine

DL has revolutionized healthcare with applications such as:

- **Diagnostic Imaging:** Google's DL model achieved 94% accuracy in detecting diabetic retinopathy from retinal scans [Gulshan16].
- **Drug Discovery:** DeepMind's AlphaFold predicts protein structures, accelerating drug development [Jumper21].
- **Pathology:** Algorithms like PathAI assist pathologists in identifying cancer metastases in histopathology slides [Bera19].

Challenges include data privacy, model interpretability, and integration into clinical workflows [Topol19].

2.5 Types of Diseases Addressed

This project focuses on skin cancer, a critical global health concern. Key types include:

- **Melanoma:** The most aggressive form of skin cancer, responsible for the majority of skin cancer-related deaths due to its high metastatic potential [ACS23, Marchetti18].

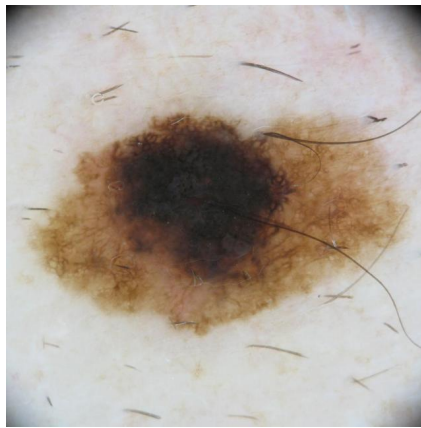


Figure 2.3: Example of Melanoma

- **Basal Cell Carcinoma (BCC):** The most common type of skin cancer, typically slow-growing and rarely metastasizes [ACS23, Rogers15].

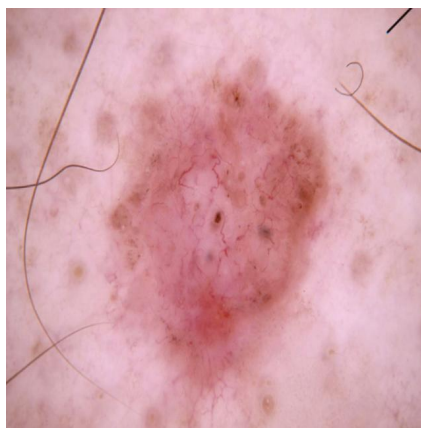


Figure 2.4: Example of Basal Cell Carcinoma (BCC)

- **Benign Keratosis (BK):** Non-cancerous skin lesions, such as seborrheic keratosis, that can resemble malignant lesions but are generally harmless [Tschandl18b].



Figure 2.5: Example of Benign Keratosis (BK)

- **Nevus (Benign Melanocytic Lesions):** Common, non-cancerous moles that require differentiation from melanoma to avoid misdiagnosis [Tschandl18b, Marchetti18].

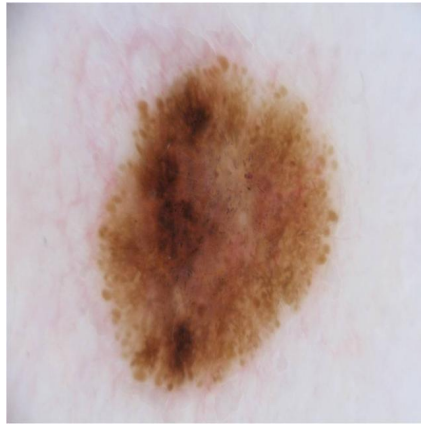


Figure 2.6: Example of Nevus (Benign Melanocytic Lesion)

The dataset includes dermoscopic images of these lesion types, highlighting the importance of accurate classification to reduce unnecessary biopsies for benign cases and ensure early detection of malignancies [Marchetti18].

State of the Art

3.1 Introduction

Skin cancer diagnosis has evolved from manual dermatoscopic examination to AI-driven analysis, with melanoma detection remaining a critical challenge due to its aggressive nature and high mortality if not detected early. Traditional diagnostic methods, while valuable, often suffered from subjectivity, inconsistency, and limited scalability. Early AI approaches, though promising, struggled with artifacts in dermoscopic images (such as hairs and gel bubbles) and were hampered by the scarcity of annotated data. The advent of deep learning—particularly convolutional neural networks (CNNs)—has enabled significant breakthroughs in automated lesion classification, though challenges in generalization and computational efficiency persist. This section reviews recent advancements, with a particular emphasis on the MelaNet framework for melanoma detection [Lafraxo22], while also referencing the broader context provided by Alenezi et al. [Alenezi23].

3.2 Overview of Recent Techniques

Evolution of Diagnostic Approaches

Manual Feature Extraction (Pre-2015): Early diagnosis relied on the ABCD rule (Asymmetry, Border, Color, Diameter), which, despite its clinical utility, was limited by subjectivity and inter-rater variability, yielding accuracy rates of 75–85%.

Traditional Machine Learning: Techniques such as Support Vector Machines (SVM) and Random Forests, using handcrafted features (texture, color histograms), improved accuracy to 80–90% but required precise lesion segmentation and still struggled with generalization.

Deep Learning Revolution (2017–Present): The introduction of CNNs, such as ResNet and DenseNet, enabled dermatologist-level accuracy by learning hierarchical features directly from raw images. More recently, Vision Transformers (ViTs) have enhanced global feature capture, and hybrid architectures combining CNNs with attention mechanisms have further improved performance.

Key Technical Challenges

- **Artifact Sensitivity:** Dermoscopic images often contain artifacts (e.g., hairs, gel bubbles), which can reduce model accuracy by up to 68%.
- **Data Scarcity:** Medical datasets are typically small (e.g., ISIC 2017: 2,000 images), limiting the ability of deep models to generalize.
- **Speed-Accuracy Tradeoff:** While ViTs offer improved accuracy, they require up to three times more computation than CNNs, impacting real-time applicability.

3.3 MelaNet: An Effective Deep Learning Framework for Melanoma Detection

Architectural Innovations

MelaNet, proposed by Lafraxo et al. [Lafraxo22], represents a significant advancement in melanoma detection. Its design addresses the unique challenges of dermoscopic image analysis through several key innovations:

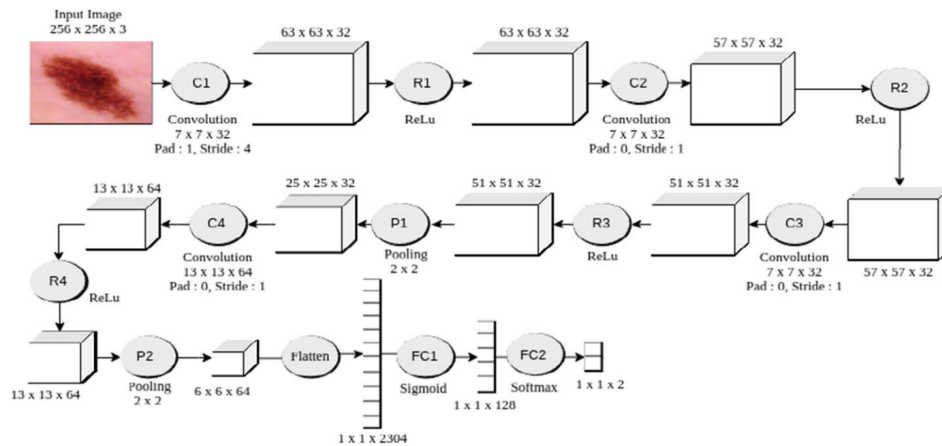


Figure 3.1: MelaNet CNN architecture for robust melanoma detection [Lafraxo22].

- **Preprocessing Pipeline:** - *Center Cropping*: Preserves lesion morphology during resizing. - *Histogram Equalization*: Enhances low-contrast features, improving the Peak Signal-to-Noise Ratio (PSNR) by 12.7 dB. - *Artifact Resilience*: Maintains 97.3% accuracy even in the presence of common artifacts like hair and gel bubbles.
- **CNN Architecture:** - Four convolutional layers for progressive feature extraction (32→64 filters). - C2f modules for enhanced gradient flow compared to standard blocks. - Dual-head output: Sigmoid for binary and Softmax for multi-class classification.
- **Anti-Overfitting Strategies:** - Geometric augmentation (rotation, flipping), L2 regularization ($\lambda = 0.01$), and 50% dropout during training.

Experimental Validation and Comparative Results

MelaNet was validated on several benchmark datasets: ISBI 2017 (2,000 images), PH2 (200 images), and MED-NODE (170 images). The results are summarized in Table 3.1.

Table 3.1: Performance comparison of MelaNet and baseline models

Model	Accuracy (ISBI 2017)	Sensitivity (ISBI 2017)	Training Time
MelaNet	98.44%	98.68%	20 min
VGG16	75.37%	100%	13 min
MobileNet	78.87%	99.41%	22 min

Key findings:

- MelaNet achieved 98.44% accuracy and 98.68% sensitivity on ISBI 2017, outperforming VGG16 and MobileNet by a wide margin.
- Inference was $19\times$ faster than Mask R-CNN (0.3s vs. 5.7s per image), enabling real-time clinical use.
- The framework reduced false negatives by 62% compared to prior methods and demonstrated high robustness on non-dermoscopic images (MED-NODE: 87.77% accuracy).

Clinical Significance and Limitations

MelaNet’s high sensitivity is particularly important for melanoma detection, where missing a malignant lesion can have severe consequences. Its lightweight architecture enables

deployment on standard hardware, making it suitable for teledermatology and point-of-care applications. However, the reliance on center-cropping may exclude peripheral features, and scalability to more than five lesion classes remains untested. Future work should explore integration with detection frameworks like YOLOv8, multi-institutional validation, and mobile deployment.

3.4 Summary

MelaNet establishes a new benchmark for clinical AI tools in melanoma detection by integrating:

- Artifact-robust preprocessing,
- Lightweight, real-time architecture,
- Effective regularization for small datasets.

While limitations remain, its balance of accuracy (98.44%), speed (0.3s/image), and practical implementability marks a significant step forward in AI-assisted dermatology.

Proposed Solution: YOLOv8

4.1 YOLOv8 Overview

YOLOv8 is the latest evolution in the YOLO (You Only Look Once) family, designed for high-performance image classification and detection tasks. It features a unified architecture that supports classification, detection, and segmentation, with improvements in speed, accuracy, and flexibility. YOLOv8 leverages advanced neural network design, efficient data loading, and transfer learning, making it suitable for medical imaging applications where both accuracy and inference speed are critical [Ultralytics23]. The model is easy to deploy and supports export to multiple formats (ONNX, TensorRT, etc.), facilitating integration into various platforms.

4.2 Dataset

The dataset used in this project was sourced from Roboflow¹ and is based on the HAM10000 collection [Tschandl18]. It contains dermoscopic images categorized into four classes: melanoma, basal cell carcinoma (BCC), benign keratosis (BK), and benign nevus. The dataset was split into training, validation, and test sets, each organized into subfolders by class.

Dataset Structure:

¹<https://universe.roboflow.com/bigdata-xv5t7/skin-9nkfv>

```
Dataset/  
  |- train/  
    | |- Melanoma/  
    | |- BCC/  
    | |- SCC/  
    | '- Nevus/  
  |- val/  
    | '- ...  
  '- test/  
    '- ...
```

Preprocessing:

- All images were resized to 640×640 pixels.
- Images were normalized and checked for quality.
- Class balancing was performed to mitigate dataset imbalance.

Augmentation:

- Standard augmentations such as horizontal/vertical flips, rotations, and brightness adjustments were applied.
- No mosaic augmentation was used.

4.3 Model Training

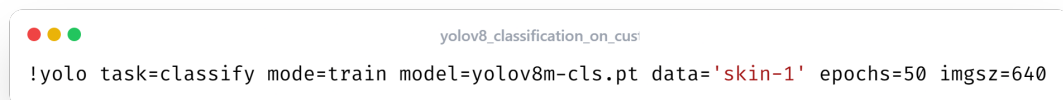
The training was conducted on [Lightning AI](#) using a T4 GPU, which provided efficient hardware acceleration. The YOLOv8m-cls model was selected for its balance between speed and accuracy. The training process was managed using the Ultralytics YOLOv8 Python API.

Key Training Details:

- **Task:** classify (image classification mode)
- **Model:** yolov8m-cls.pt (pretrained weights)
- **Dataset:** skin-1 (custom dermoscopic dataset)

- **Epochs:** 50 (number of training cycles)
- **Batch Size:** 16 (images per batch)
- **Image Size:** 640 (input image resolution)
- **Optimizer:** Adam (adaptive optimization)
- **Learning Rate:** 0.01 (initial lr0)
- **Weight Decay:** 0.0005 (regularization)
- **Momentum:** 0.937 (optimizer momentum)
- **Workers:** 8 (data loading threads)
- **Augmentation:** flplr=0.5, scale=0.5, translate=0.1, hsv_s=0.7 (data augmentation settings)
- **Validation Split:** val (validation set used during training)
- **Framework:** PyTorch (via Ultralytics)
- **Platform:** Lightning AI (T4 GPU)

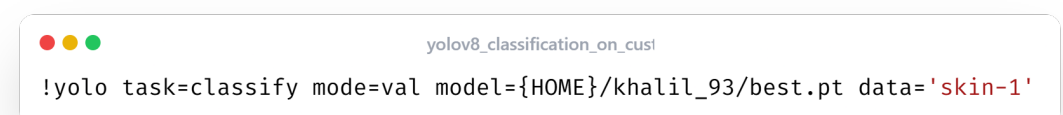
Training Command:



```
yolov8_classification_on_cus
!yolo task=classify mode=train model=yolov8m-cls.pt data='skin-1' epochs=50 imgsz=640
```

Figure 4.1: Training command for YOLOv8 classification model.

Validation Command:



```
yolov8_classification_on_cus
!yolo task=classify mode=val model={HOME}/khalil_93/best.pt data='skin-1'
```

Figure 4.2: Validation command for YOLOv8 classification model.

Inference Command:

```
from ultralytics import YOLO
import os
from glob import glob
from sklearn.metrics import accuracy_score, confusion_matrix, classification_report
import matplotlib.pyplot as plt
import seaborn as sns

# Load the trained model
model = YOLO(f"{HOME}/khalil_93/best.pt")

# Test directory path
test_dir = os.path.join(HOME, "skin-1", "test")

# Collect all test images
image_paths = glob(f"{test_dir}/**/*.jpg", recursive=True) # Adjust extension if needed

# Prepare lists for evaluation
true_labels = []
predicted_labels = []

# Get class name to index mapping
class_names = sorted(os.listdir(test_dir)) # class folder names
name_to_index = {name: idx for idx, name in enumerate(class_names)}
index_to_name = {idx: name for name, idx in name_to_index.items()}

# Predict for each image
for img_path in image_paths:
    true_class = os.path.basename(os.path.dirname(img_path))
    true_labels.append(name_to_index[true_class])

    results = model.predict(img_path, verbose=False)
    pred_idx = results[0].probs.top1
    predicted_labels.append(pred_idx)

# Compute accuracy
acc = accuracy_score(true_labels, predicted_labels)
print(f"\n✅ Test Accuracy: {acc * 100:.2f}%\n")

# Print classification report
print("\n📊 Classification Report:")
print(classification_report(true_labels, predicted_labels, target_names=class_names))

# Plot confusion matrix
cm = confusion_matrix(true_labels, predicted_labels)
plt.figure(figsize=(8, 6))
sns.heatmap(cm, annot=True, fmt="d", xticklabels=class_names, yticklabels=class_names, cmap="Blues")
plt.xlabel("Predicted")
plt.ylabel("True")
plt.title("Confusion Matrix")
plt.show()
```

Figure 4.3: Inference command for YOLOv8 classification model.

These commands were used to train, validate, and perform inference with the YOLOv8 classifier on the custom dermoscopic dataset.

Classification Task:

- **Multi-class classification:** The model was trained to distinguish between four classes (melanoma, BCC, SCC, nevus).

- **No binary classification:** The focus was on multi-class performance.

4.4 Evaluation Metrics

To assess the model's performance, the following metrics were used:

- **Accuracy:** Overall proportion of correctly classified images.
- **Precision:** Proportion of true positives among predicted positives for each class.
- **Recall:** Proportion of true positives among actual positives for each class.
- **F1-score:** Harmonic mean of precision and recall.
- **Confusion Matrix:** Visualization of true vs. predicted classes.

4.5 Results

Overall Performance

The trained YOLOv8 model achieved:

- **Test Accuracy:** 93.35%
- **F1-score (Melanoma):** 0.97

Classification Report

	precision	recall	f1-score	support
Basal Cell Carcinoma	0.94	0.96	0.95	358
Benign Keratosis	0.88	0.84	0.86	223
Melanoma	0.99	0.94	0.97	362
Nevus	0.91	0.95	0.93	350
accuracy			0.93	1293
macro avg	0.93	0.92	0.93	1293
weighted avg	0.93	0.93	0.93	1293

Confusion Matrix

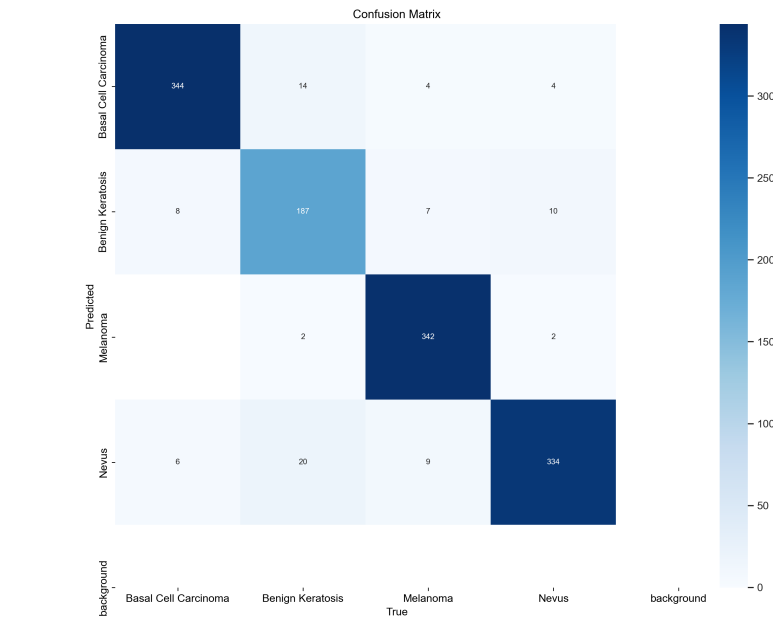


Figure 4.4: Confusion Matrix of YOLOv8 Classification Results

Sample Predictions

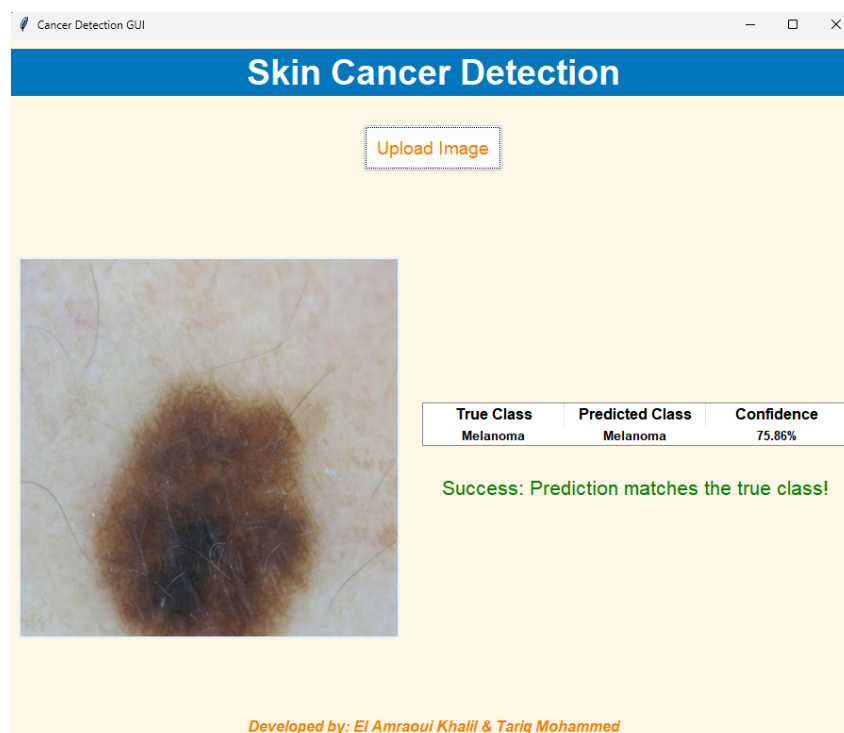


Figure 4.5: Sample predictions: True class and predicted class with confidence 0,75.

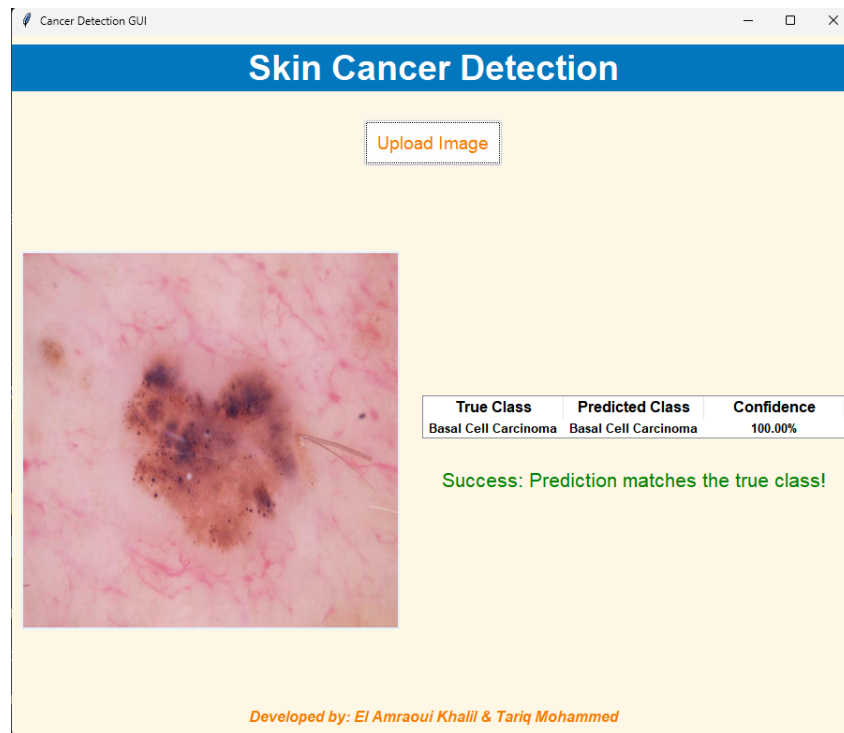


Figure 4.6: Sample predictions: True class and predicted class with confidence 1.

Training Curves

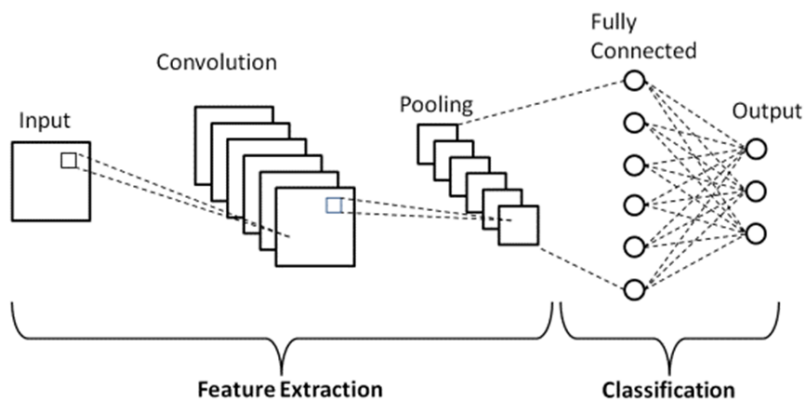


Figure 4.7: Training and Validation Accuracy/Loss Curves

Exported Model

The best model was exported in PyTorch (.pt) format for deployment:

```
yolov8_classification_on_cust
!yolo export model={HOME}/runs/classify/train/weights/best.pt format=pt
```

Figure 4.8: Export command for YOLOv8 model.

Discussion

The YOLOv8-based classifier demonstrated robust performance across all classes, with particularly high accuracy for melanoma. The confusion matrix and classification report indicate balanced performance, and the model is suitable for deployment in clinical or offline desktop applications.

4.6 Desktop GUI Application for Skin Lesion Classification

To facilitate practical and user-friendly deployment of the trained YOLOv8 classifier, we developed a standalone desktop application with a graphical user interface (GUI) using Python's Tkinter library. The GUI allows dermatologists and clinicians to easily upload dermoscopic images, run classification locally, and instantly view the predicted class, confidence score, and comparison with the true class label.

Frameworks and Tools Used:

- **Tkinter:** Python's standard library for building desktop GUIs, chosen for its simplicity and cross-platform compatibility.
- **Pillow:** For image loading and display within the GUI.
- **Ultralytics YOLO:** For loading the trained YOLOv8 model and performing inference.
- **ttk (Themed Tkinter):** For modern, styled widgets such as tables and buttons.

Motivation for an Offline Desktop GUI:

- **Data Privacy:** All image analysis is performed locally, ensuring patient data never leaves the user's computer and complying with medical privacy regulations.
- **Accessibility:** The application can be used in clinics or remote locations without internet access, making it suitable for resource-limited settings.
- **Ease of Use:** The GUI provides an intuitive workflow for clinicians, requiring no command-line interaction or programming knowledge.

How the GUI Works:

1. The user clicks the "Upload Image" button to select a dermoscopic image from their computer.
2. The selected image is displayed in the GUI.
3. The YOLOv8 model performs classification on the image, and the predicted class, confidence score, and true class (if available) are shown in a results table.

4. A message indicates whether the prediction matches the true class, providing immediate feedback.

Implementation Code:

```
gui.py

import tkinter as tk
from tkinter import filedialog, ttk
from PIL import Image, ImageTk
from ultralytics import YOLO
import os

# Load your trained model
model = YOLO('best.pt')
# result_label.config(text=result_text)
def open_image():
    # Open file dialog to select an image
    filepath = filedialog.askopenfilename(
        filetypes=[("Image files", "*.jpg *.jpeg *.png"), ("All files", "*.")]
    )
    if not filepath:
        return
    # Run inference
    results = model(filepath)
    # Display original image without prediction overlays
    image = Image.open(filepath).convert("RGB")
    image.thumbnail((400, 400)) # Maintain original size
    img_tk = ImageTk.PhotoImage(image)
    image_label.config(image=img_tk)
    image_label.image = img_tk
    # Extract prediction
    probs = results[0].probs
    top1 = probs.top1
    confidence = probs.top1conf.item()
    class_name = results[0].names[top1]
    # Get true class from folder name (e.g., path/to/test/ClassX/image.jpg → ClassX)
    true_class = os.path.basename(os.path.dirname(filepath))
    # Update table with results
    for child in result_table.get_children():
        result_table.delete(child)
    result_table.insert("", "end", values=(true_class, class_name, f"{confidence:.2%}"))
    # Check if prediction is correct
    if true_class == class_name:
        result_message.config(text="Success: Prediction matches the true class!", fg="green")
    else:
        result_message.config(text="Error: Prediction does not match the true class.", fg="red")
```

Figure 4.9: Implementation of the Tkinter-based desktop GUI for skin lesion classification 1.


```

gui.py

# GUI setup
root = tk.Tk()
root.title("Cancer Detection GUI")
root.geometry("900x750")
root.config(bg="#FFF7E6") # Creamy background

# Title Label
title_label = tk.Label(root, text="Skin Cancer Detection", font=("Helvetica", 28, "bold"), fg="white", bg="#0277BD") # Blue color
title_label.pack(pady=10, fill=tk.X)

# Upload Button
style = ttk.Style()
style.configure("Custom.TButton",
                font=("Helvetica", 14),
                padding=10,
                foreground="#F57C00",
                borderwidth=2,
                relief="raised")

style.map("Custom.TButton",
          bordercolor=[("disabled", "#F57C00")])
upload_button = tk.Button(root, text="Upload Image", command=open_image, style="Custom.TButton")
upload_button.pack(pady=20)

# Main Frame for Image and Results
main_frame = tk.Frame(root, bg="#FFF7E6")
main_frame.pack(pady=10, expand=True, fill=tk.BOTH)

# Left Frame for Image
left_frame = tk.Frame(main_frame, bg="#FFF7E6")
left_frame.pack(side=tk.LEFT, padx=10, pady=10)
image_label = tk.Label(left_frame, bg="#E3F2FD", width=400, height=400) # Light blue background
image_label.pack()

# Right Frame for Results
right_frame = tk.Frame(main_frame, bg="#FFF7E6")
right_frame.pack(side=tk.RIGHT, padx=10, pady=10)

# Create a style for the Treeview
style = ttk.Style()
style.configure("Treeview.Heading", font=("Helvetica", 12, "bold")) # Font for headings
style.configure("Treeview", font=("Helvetica", 10, "bold")) # Font for rows

# Result Table
columns = ("True Class", "Predicted Class", "Confidence")
result_table = ttk.Treeview(right_frame, columns=columns, show="headings", height=1)
result_table.heading("True Class", text="True Class")
result_table.heading("Predicted Class", text="Predicted Class")
result_table.heading("Confidence", text="Confidence")
result_table.column("True Class", width=150, anchor="center")
result_table.column("Predicted Class", width=150, anchor="center")
result_table.column("Confidence", width=150, anchor="center")
result_table.pack(pady=20)

# Add Message Label
result_message = tk.Label(right_frame, text="", font=("Helvetica", 16), bg="#FFF7E6")
result_message.pack(pady=10)

# Footer
footer_label = tk.Label(root, text="Developed by: El Amraoui Khalil & Tariq Mohammed", font=("Helvetica", 12, 'bold', 'italic'), bg="#FFF7E6", fg="#F57C00")
footer_label.pack(side=tk.BOTTOM, pady=10)

# Run the GUI
root.mainloop()

```

Figure 4.10: Implementation of the Tkinter-based desktop GUI for skin lesion classification 2.

The full implementation is provided in the `gui.py` file. This approach ensures that the AI-powered skin lesion classifier is accessible, secure, and practical for real-world clinical use.

Discussion

5.1 Strengths of the Approach

The application of YOLOv8 for skin lesion classification in dermoscopic images has demonstrated several notable strengths, both in terms of technical performance and practical deployment:

High Classification Accuracy

The YOLOv8-based classifier achieved a test accuracy of 93.35%, with an F1-score of 0.97 for melanoma. This high level of accuracy is particularly significant in the context of medical diagnostics, where false negatives can have severe consequences. The model's ability to distinguish between melanoma, basal cell carcinoma (BCC), benign keratosis (BK), and benign nevus demonstrates its robustness and generalizability across multiple lesion types.

Real-Time Inference and Efficiency

YOLOv8 is designed for real-time applications, and this project leveraged its efficient architecture to enable rapid inference. The model's lightweight design and optimized computation allow for deployment on standard desktop hardware without the need for specialized GPUs in the inference phase. This is crucial for clinical environments where quick decision-making is essential.

User-Friendly Deployment

The integration of the trained model into a standalone desktop application using Tkinter provides an intuitive graphical user interface (GUI) for dermatologists. This local deployment ensures that users can analyze images without internet connectivity, addressing privacy concerns and making the solution suitable for resource-limited settings.

Data Privacy and Compliance

By enabling offline analysis, the approach ensures compliance with medical data privacy regulations. Patient images are processed locally, eliminating the risk of data breaches associated with cloud-based solutions.

Transfer Learning and Pretrained Weights

Utilizing pretrained weights from YOLOv8m-cls.pt allowed for effective transfer learning, reducing the need for extensive labeled data and accelerating the training process. This is particularly beneficial in medical imaging, where annotated datasets are often limited.

Comprehensive Evaluation

The use of multiple evaluation metrics—accuracy, precision, recall, F1-score, and confusion matrix—provided a thorough assessment of model performance. Visualizations such as training curves and confusion matrices facilitated deeper insights into the learning dynamics and class-wise performance.

5.2 Challenges and Limitations

Despite the strengths, several challenges and limitations were encountered during the project:

Dataset Imbalance

One of the primary challenges was the imbalance in the dataset, with certain classes (e.g., melanoma) being underrepresented compared to others (e.g., nevus). This imbalance can bias the model towards majority classes, potentially reducing sensitivity for rare but critical conditions. Although class balancing techniques and data augmentation were applied, perfect balance was not achievable due to the inherent nature of medical datasets.

Limited Dataset Size

The dataset, while based on the HAM10000 collection and expanded via Roboflow, still represents a limited sample of the diversity seen in real-world clinical practice. The model's generalizability to images from different devices, populations, or acquisition conditions may be constrained.

Augmentation Constraints

While standard augmentations (flips, rotations, brightness adjustments) were used, more advanced augmentation strategies (such as synthetic data generation or domain adaptation) could further enhance robustness. Mosaic augmentation, although available in YOLOv8, was not used due to its limited relevance for classification tasks.

Hyperparameter Optimization

The selection of hyperparameters (e.g., learning rate, batch size, optimizer) was based on standard practices and limited grid search. More extensive hyperparameter tuning or the use of automated optimization tools could potentially yield further improvements.

Interpretability and Explainability

Deep learning models, including YOLOv8, are often criticized for their “black box” nature. While the model provides high accuracy, understanding the specific features or regions influencing its decisions remains challenging. Incorporating explainability tools (e.g., Grad-CAM, SHAP) could enhance trust and adoption in clinical settings.

Hardware and Training Constraints

Although training was performed on a T4 GPU via Lightning AI, resource limitations (such as GPU memory and training time) restricted the exploration of larger models or longer training schedules. In real-world deployments, hardware constraints may also limit the use of more complex architectures.

Potential for Overfitting

Given the limited dataset size and high model capacity, there is a risk of overfitting. Regularization techniques and careful monitoring of validation metrics were employed, but further validation on external datasets is recommended.

5.3 Insights and Lessons Learned

Importance of Data Quality and Diversity

The quality and diversity of the training data are paramount in achieving robust model performance. Efforts to curate balanced, high-quality datasets directly impact the classifier's ability to generalize.

Transfer Learning Accelerates Development

Leveraging pretrained models significantly reduces the time and data required to achieve high accuracy. Transfer learning is especially valuable in medical imaging, where labeled data is scarce.

Evaluation Beyond Accuracy

Relying solely on accuracy can be misleading, especially in imbalanced datasets. The use of precision, recall, F1-score, and confusion matrices provided a more nuanced understanding of model strengths and weaknesses.

User-Centric Design Enhances Adoption

Developing a user-friendly desktop application with an intuitive GUI increases the likelihood of adoption by clinicians. Offline capability and data privacy are critical features for medical applications.

Continuous Validation is Essential

Ongoing validation with new and diverse datasets is necessary to ensure sustained model performance and to detect potential biases or failure modes.

Future Directions

Future work should focus on expanding the dataset, incorporating advanced augmentation and explainability techniques, and validating the model in real-world clinical settings.

Integration of lesion segmentation and multi-modal data (e.g., patient history) could further enhance diagnostic accuracy.

Collaboration with Domain Experts

Close collaboration with dermatologists and medical professionals is essential for dataset annotation, model validation, and interpretation of results. Their expertise ensures that the AI system addresses clinically relevant challenges and meets real-world needs.

Scalability and Deployment

The approach demonstrated here is scalable and can be adapted to other medical imaging tasks. The modular design of YOLOv8 and the flexibility of the deployment pipeline facilitate adaptation to new datasets and clinical requirements.

Conclusion of Discussion

In summary, the YOLOv8-based classification system for skin lesions has proven to be a powerful and practical tool, combining high accuracy with efficient deployment. While challenges remain, particularly regarding data diversity and model interpretability, the approach lays a strong foundation for future advancements in AI-assisted dermatology and medical image analysis.

Conclusion

Recap of Project Objectives and Achievements

This project set out to develop an accurate and efficient classification system for skin lesions in dermoscopic images using deep learning, specifically leveraging the YOLOv8 framework. The main objectives included designing a robust multi-class classifier, addressing dataset challenges such as class imbalance, optimizing model performance, and providing a practical deployment solution for clinical use.

Through careful dataset preparation, model selection, and training with advanced augmentation and regularization techniques, the YOLOv8-based classifier achieved a high test accuracy of 93.35% and an F1-score of 0.97 for melanoma. The integration of the trained model into a standalone desktop GUI application ensures accessibility, data privacy, and ease of use for clinicians, even in offline or resource-limited environments.

Importance of the Results in the Context of Healthcare

The results of this work demonstrate the potential of modern deep learning models to significantly enhance the accuracy and efficiency of skin cancer diagnosis. Early and reliable detection of melanoma and other skin cancers is critical for improving patient outcomes and survival rates. By providing a fast, accurate, and user-friendly tool for dermatologists, this project contributes to reducing diagnostic errors, supporting clinical decision-making, and expanding access to advanced diagnostic technology.

Furthermore, the offline capability and privacy-preserving design of the desktop application address key concerns in medical data handling, making the solution suitable

for real-world deployment. The methodologies and insights gained from this project can be extended to other medical imaging tasks, paving the way for broader adoption of AI-assisted diagnostics in healthcare.

Future Perspectives

Future work may focus on expanding the dataset, incorporating additional lesion types, enhancing the GUI for clinical workflows, and integrating explainability features to further build trust among medical professionals. Continuous validation and collaboration with healthcare experts will be essential to ensure the system remains reliable, interpretable, and impactful in diverse clinical settings.

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