SPINEX

AUTOMATED SPINAL AND POSTURE DEFORMITY DETECTION SYSTEM

GUIDE:

MS. MEENU MATHEW

GROUP 8:

NEHA DAVIS

NEHA MARIAM MATHEW

PRIYA ANTO

SHREYA SUNIL

CONTENTS

INTRODUCTION

- Spinal deformities are abnormal curvatures or alignments of the spine that can affect balance, posture, and overall health.
- Common types include:
  - Scoliosis – sideways curvature of the spine.
  - Kyphosis – excessive outward curvature, leading to a hunched back.
  - Lordosis – exaggerated inward curvature of the lower back.

INTRODUCTION

- These conditions may be present at birth, develop during growth, or result from injury, degenerative diseases, or poor posture.
- Symptoms can include back pain, uneven shoulders or hips, restricted movement, and in severe cases, respiratory or neurological issues.
- Early detection and accurate diagnosis are vital to prevent progression and guide appropriate treatment.

PROBLEM STATEMENT

- The traditional diagnosis of spinal deformities relies heavily on manual analysis, which is prone to human error and inconsistencies.
- There is a need for an automated system that can accurately detect, classify, and recommend treatment for conditions like scoliosis, kyphosis, and lordosis to improve diagnostic efficiency and reliability.

PURPOSE AND NEED

- The purpose of the SpineX project is to develop an automated system that enhances the diagnosis and management of spinal deformities using deep learning techniques.
- There is a critical need for such a system to reduce diagnostic time, improve accuracy, and provide consistent, objective results for conditions like scoliosis, kyphosis, and lordosis.

PROJECT OBJECTIVE

- Enhance spinal image quality using image processing techniques.
- Apply deep learning models to detect spinal deformity like scoliosis.
- Automate keypoint detection and enable manual refinement to assess spinal curvature using Cobbs Angle Measurement.
- Evaluate spinal deformity severity and recommend appropriate treatment.
- Identify postural abnormalities using advanced convolutional models and suggest treatments.

LITERATURE SURVEY

Name of the Author(s)	Methods Used	Advantages	Disadvantages
Nguyen et al. (2021)	Convolutional Neural Networks (CNNs), Attention Mechanisms	High accuracy in lesion localization and classification in spinal X-rays.	Requires a large, annotated dataset for training, which may not always be available.
Zhang and Chung (2024)	Transformer-based Network, Multi-scale Feature Fusion	Improved precision and robustness in vertebra landmark localization.	The complex architecture may demand high computational resources.
Wang et al. (2022)	U-Net with Dense Connections, Data Augmentation	Enhanced segmentation performance in complex or noisy MRI images.	Needs a large amount of annotated data for effective model training.
Zhang et al. (2023)	Deep CNN with Residual Blocks, Transfer Learning	High accuracy in detecting and classifying lumbar disc herniation.	Performance can vary depending on the quality and diversity of MRI data used for training.

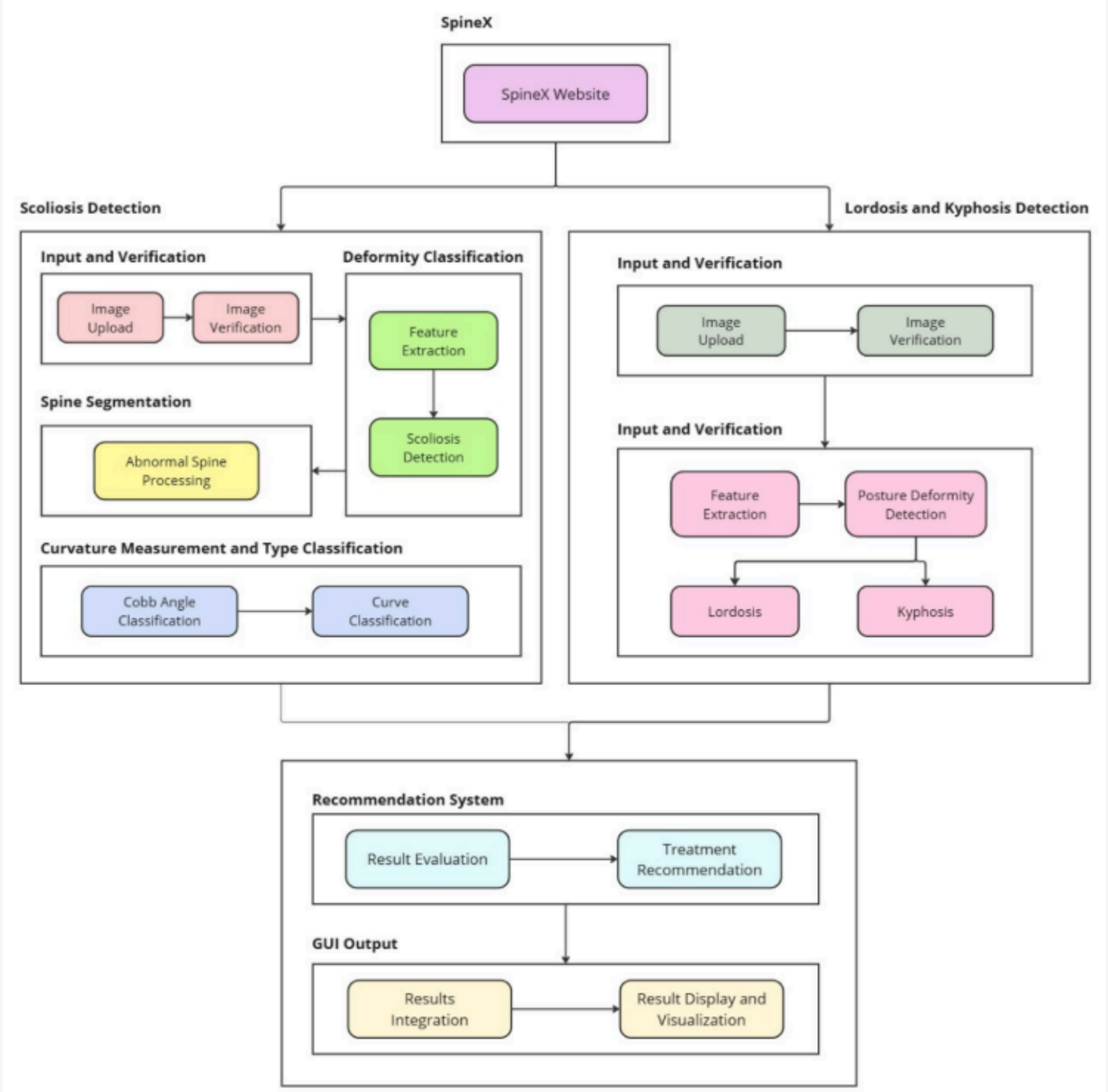
PROPOSED METHOD

- Collect and preprocess spinal X-ray images of both normal and scoliosis cases using image enhancement techniques.
- Train a CNN model and a Transfer Learning model with InceptionV3 as the base to classify X-rays into scoliosis or normal categories with improved accuracy.
- Apply spinal segmentation to automatically detect keypoints along the spine, with an option for manual refinement to ensure precise Cobb angle measurement and identify the curvature type for severity assessment.

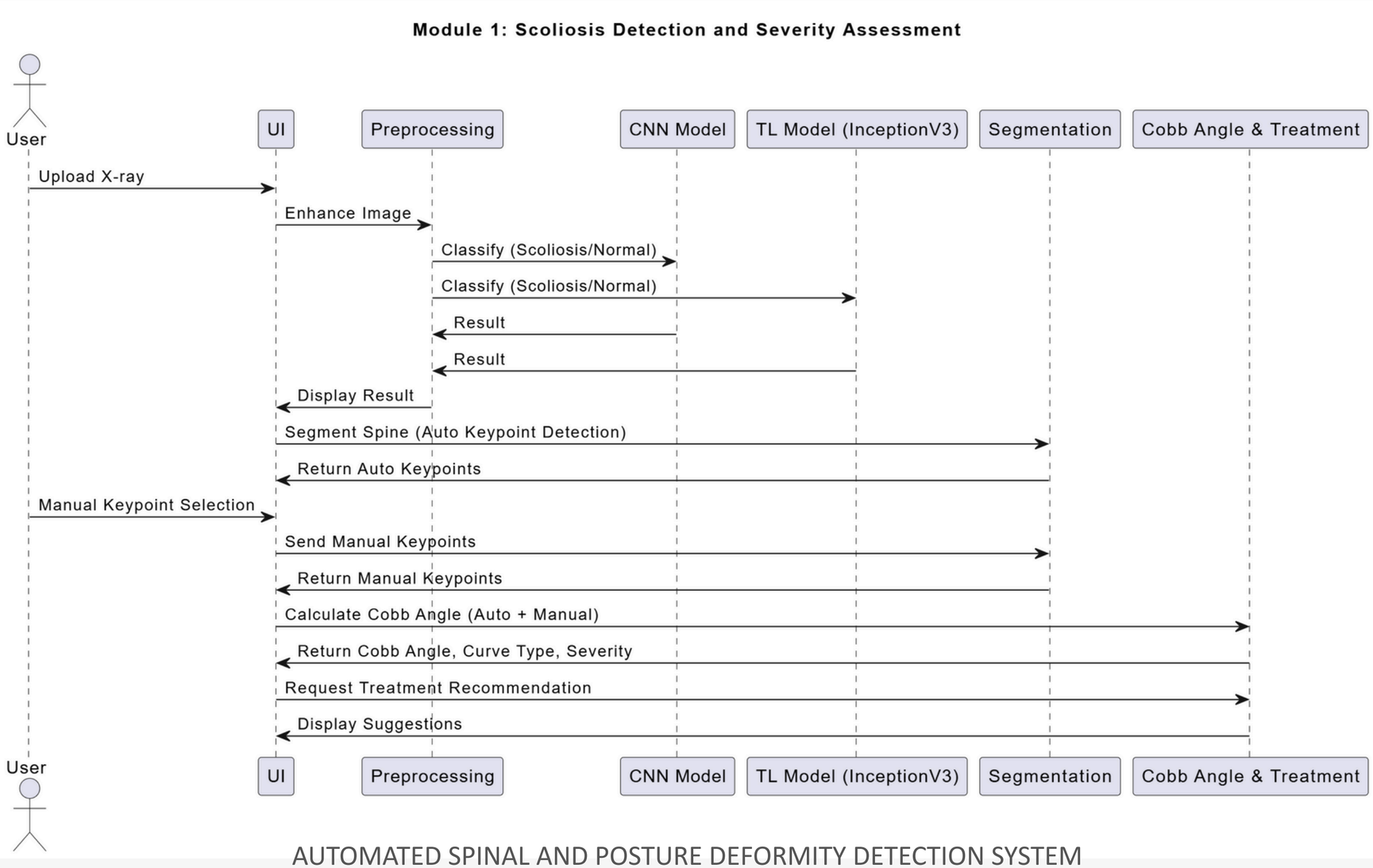
PROPOSED METHOD

- Assess scoliosis severity and generate treatment recommendations based on Cobb angle measured and the curvature type detected.
- Collect and preprocess side-view posture images for deformity analysis.
- Use a Transfer Learning model based on EfficientNetB0 to classify posture images into lordosis, kyphosis, or normal, and suggest appropriate corrective measures or treatments.

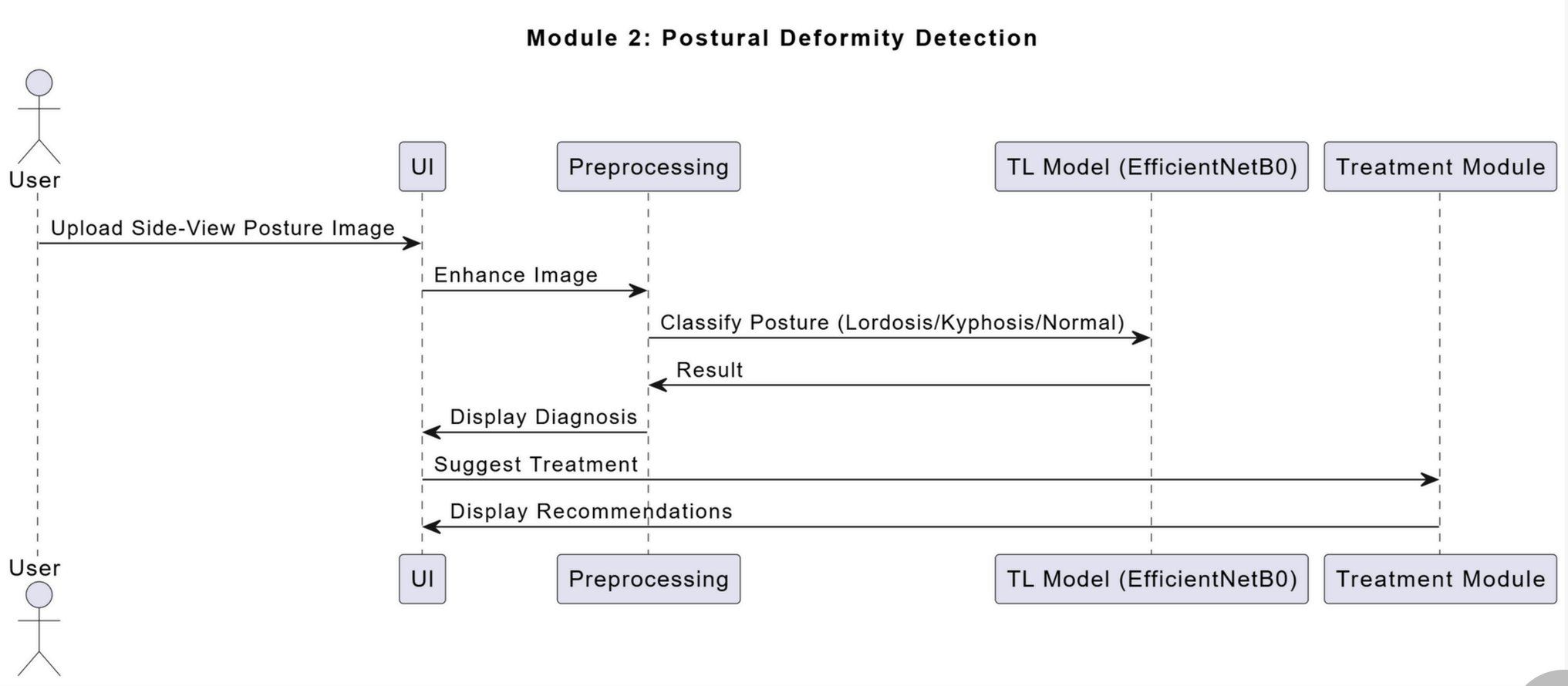
ARCHITECTURE DIAGRAM


SpineX
SpineX Website
Scoliosis Detection
Lordosis and Kyphosis Detection
Input and Verification
Image Upload
Image Verification
Deformity Classification
Feature Extraction
Scoliosis Detection
Spine Segmentation
Abnormal Spine Processing
Curvature Measurement and Type Classification
Cobb Angle Classification
Curve Classification
Input and Verification
Image Upload
Image Verification
Input and Verification
Feature Extraction
Posture Deformity Detection
Lordosis
Kyphosis
Recommendation System
Result Evaluation
Treatment Recommendation
GUI Output
Results Integration
Result Display and Visualization

SEQUENCE DIAGRAM



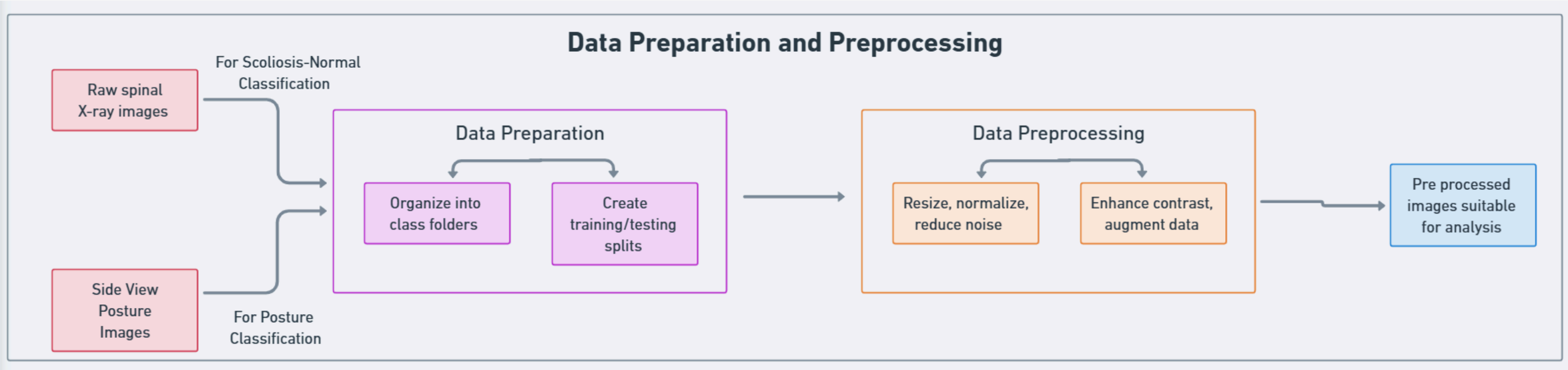
SEQUENCE DIAGRAM



MODULES

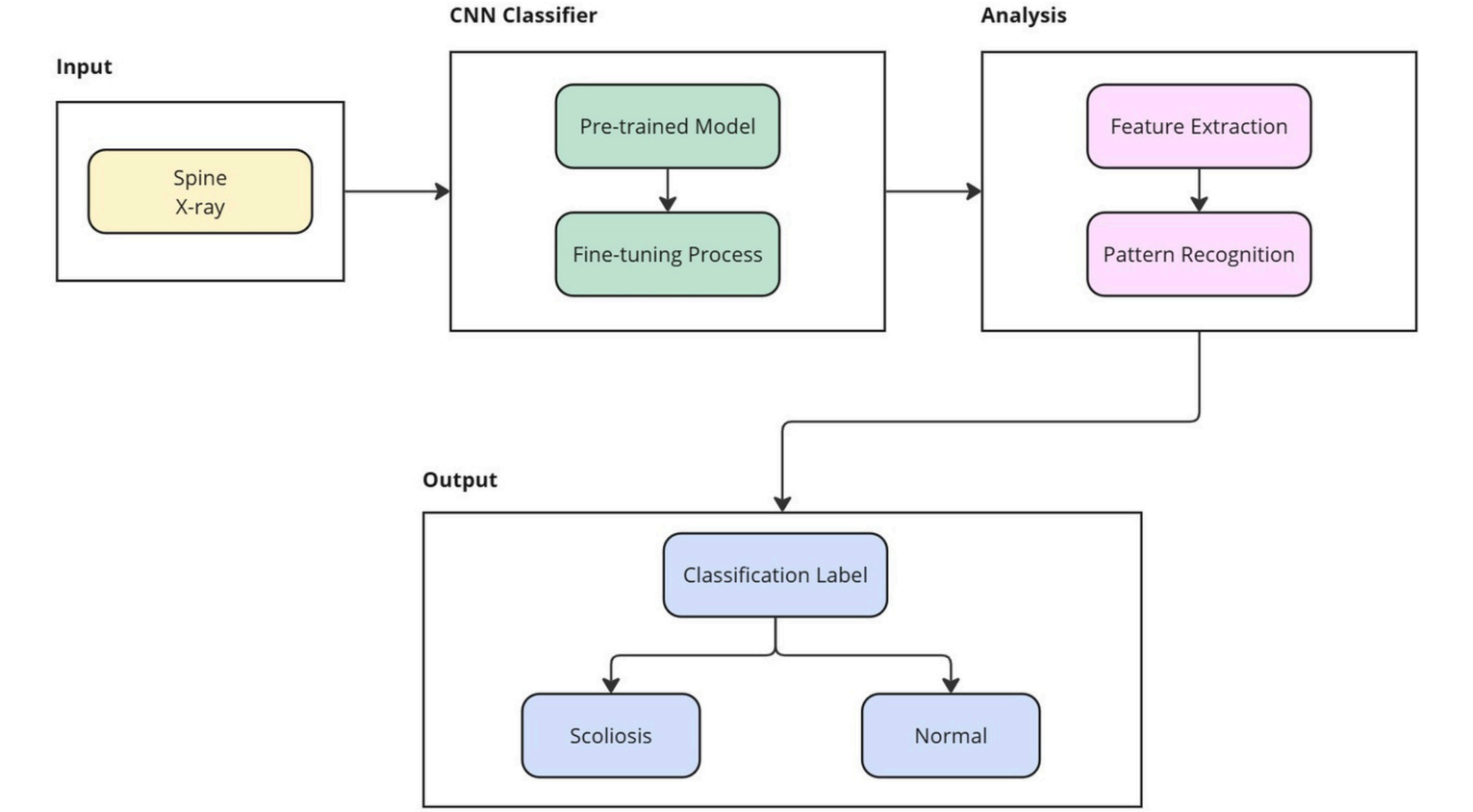
- **Data Collection & Preparation**
- **Spinal Deformity Classification**
- **Spine Segmentation**
- **Curvature Measurement & Curve Type Classification**
- **Posture Deformity Detection**
- **Treatment Guidance & User Interface**

1. DATA PREPARATION AND PREPROCESSING



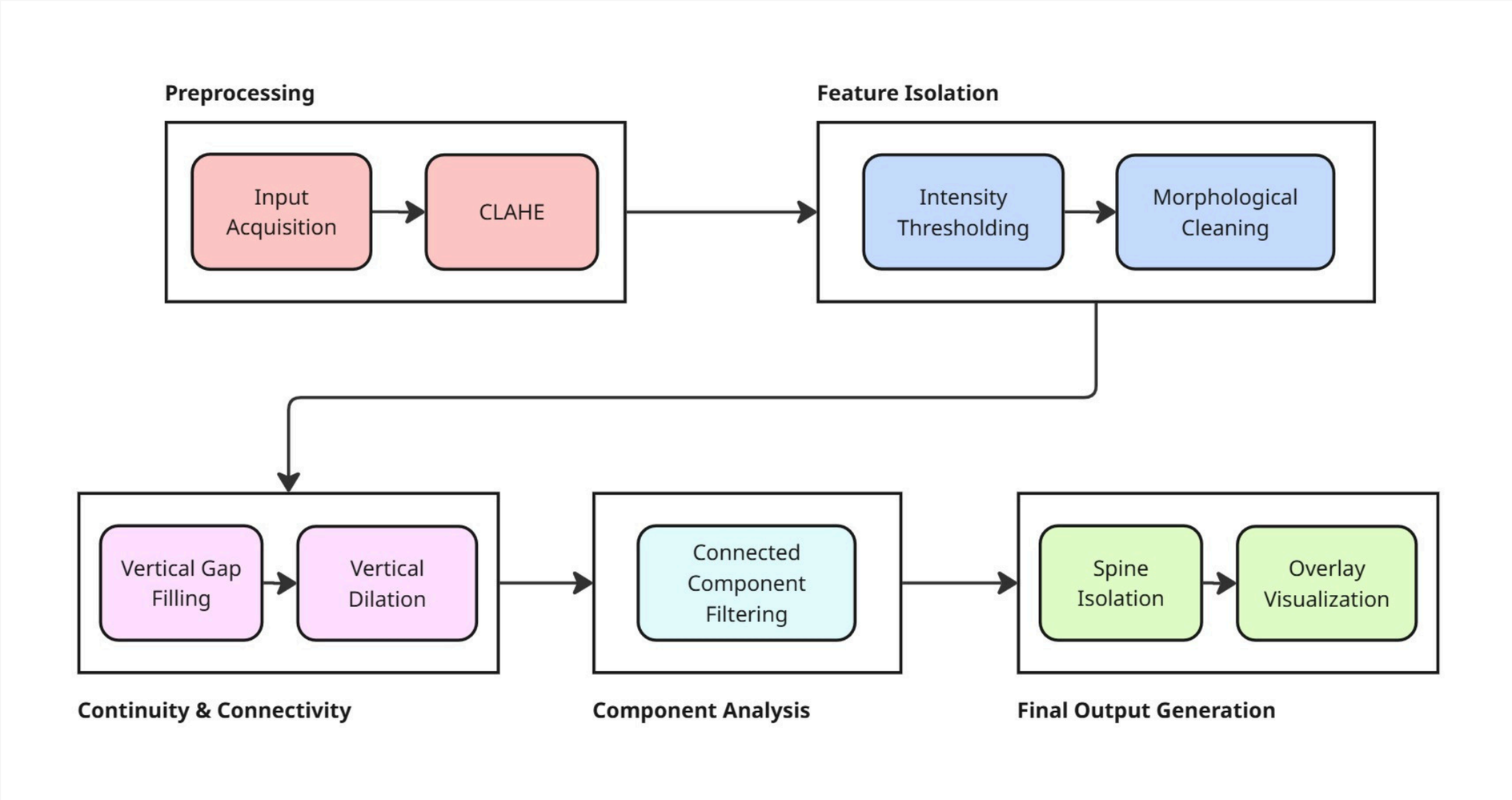
- Obtain X-ray images for Scoliosis classification and side-view posture images for Spine Deformity classification.
- Resize images, convert to grayscale, and normalize pixel values.
- Apply data augmentation techniques like rotation, flipping, and zooming.
- Organize X-ray images into two folders: Normal and Scoliosis. Organize posture images into three folders: Neutral, Lordosis, and Kyphosis.
- Split the dataset into 80% training, 10% validation, and 10% testing.

2. SPINAL DEFORMITY CLASSIFICATION



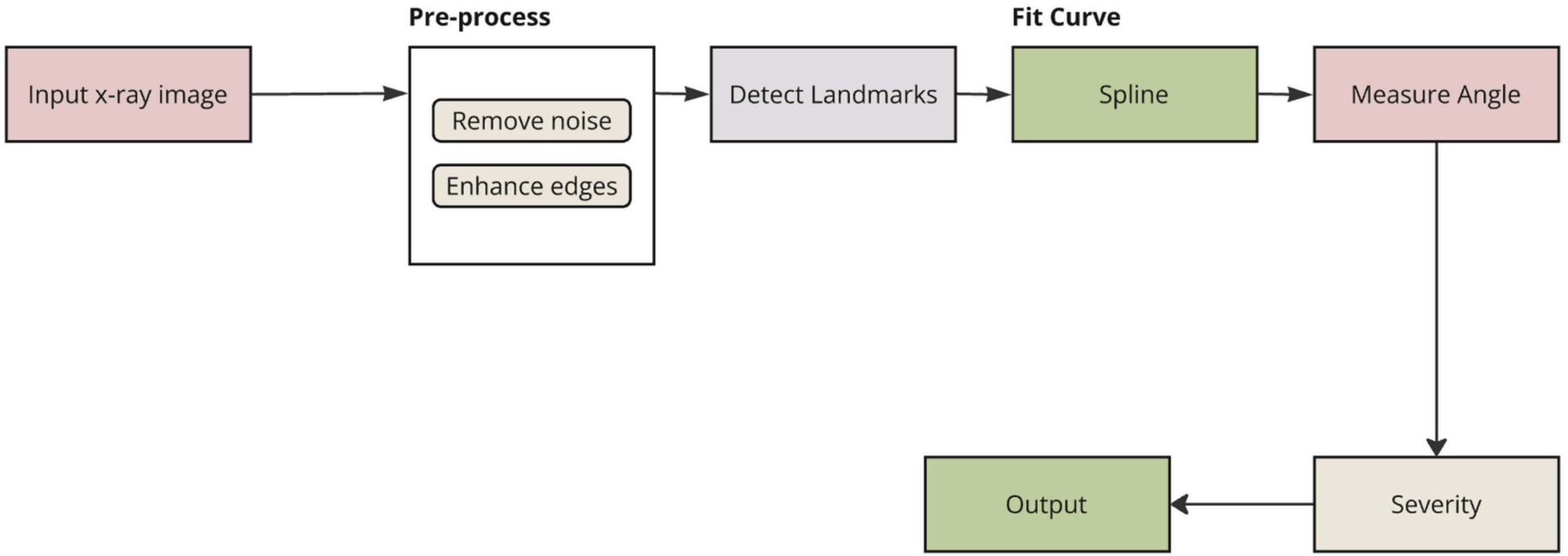
- Developed two models for scoliosis detection from X-ray images:
  - A custom CNN model trained from scratch to learn spatial features specific to spinal curvature.
  - A Transfer Learning model using InceptionV3 as the base, leveraging pre-trained weights for improved generalization on limited medical data.
- Both models classify X-ray images into scoliosis and normal categories.
- Evaluated model performance using accuracy, precision, recall, and confusion matrices to compare effectiveness.

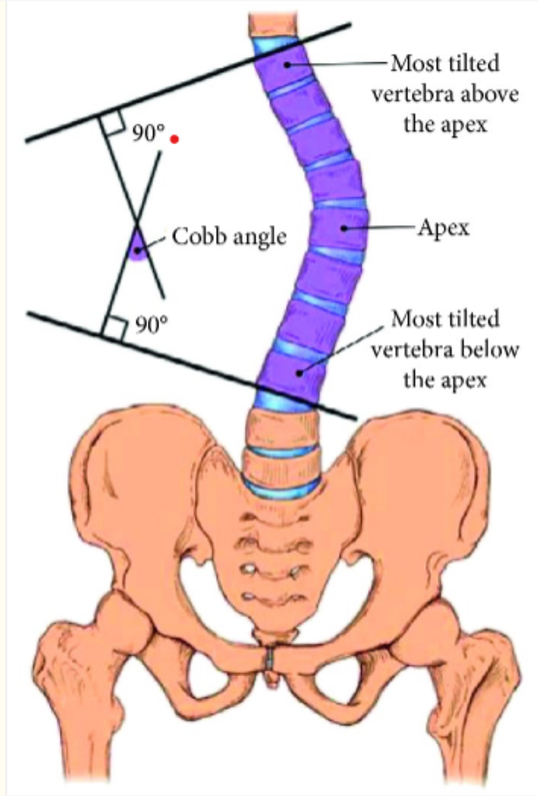
3. SPINE SEGMENTATION



- The X-ray image is first enhanced using CLAHE to improve contrast and highlight bone structures.
- A central vertical region is extracted and thresholded to isolate the spine area.
- Morphological operations and vertical continuity checks are applied to clean and connect the spine.
- The spine is isolated using component filtering and visualized with an overlay on the original image.
- Segmentation aids in automatically detecting keypoints along the spine, which are essential for assessing spinal curvature using Cobb’s angle .

4. CURVATURE MEASUREMENT & CURVE TYPE CLASSIFICATION

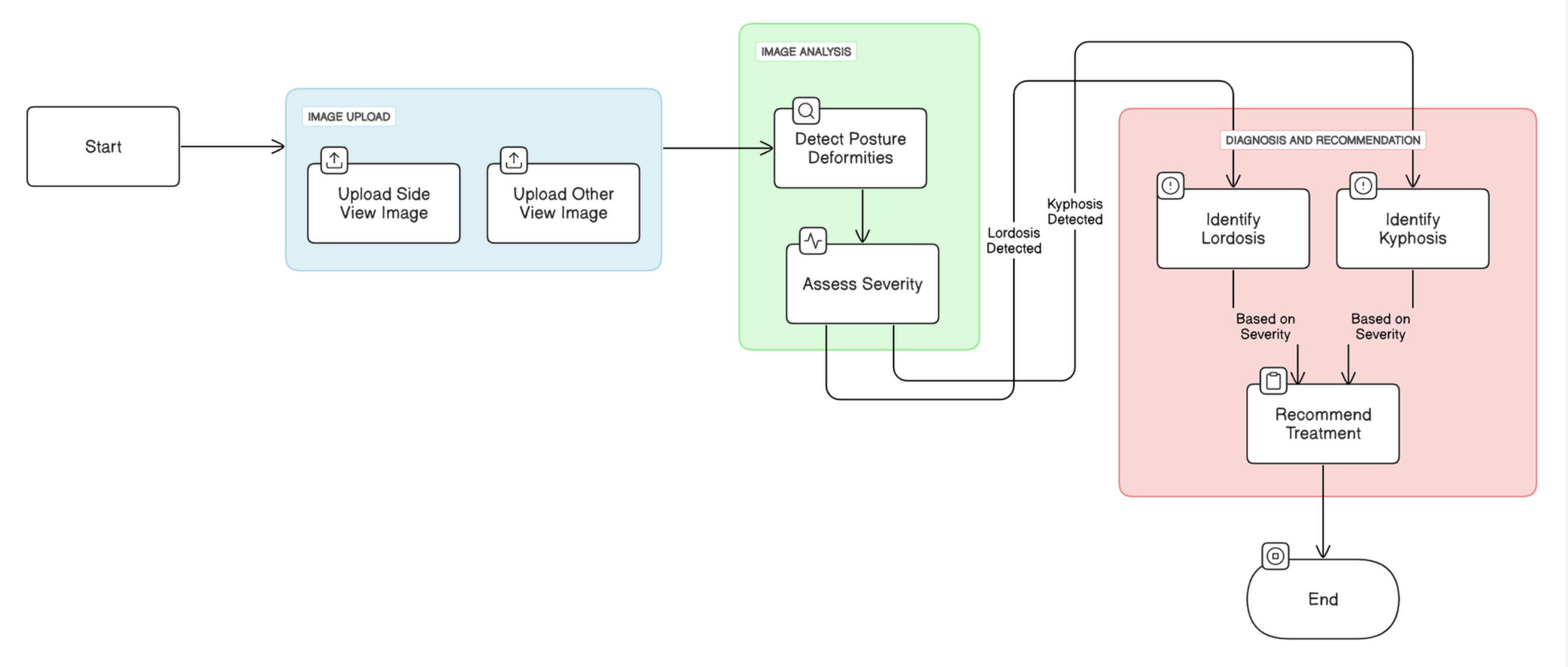




Cobb angle	Definition
0°–10°	Spinal curve
10°–20°	Mild scoliosis
20°–40°	Moderate scoliosis
>40°	Severe scoliosis

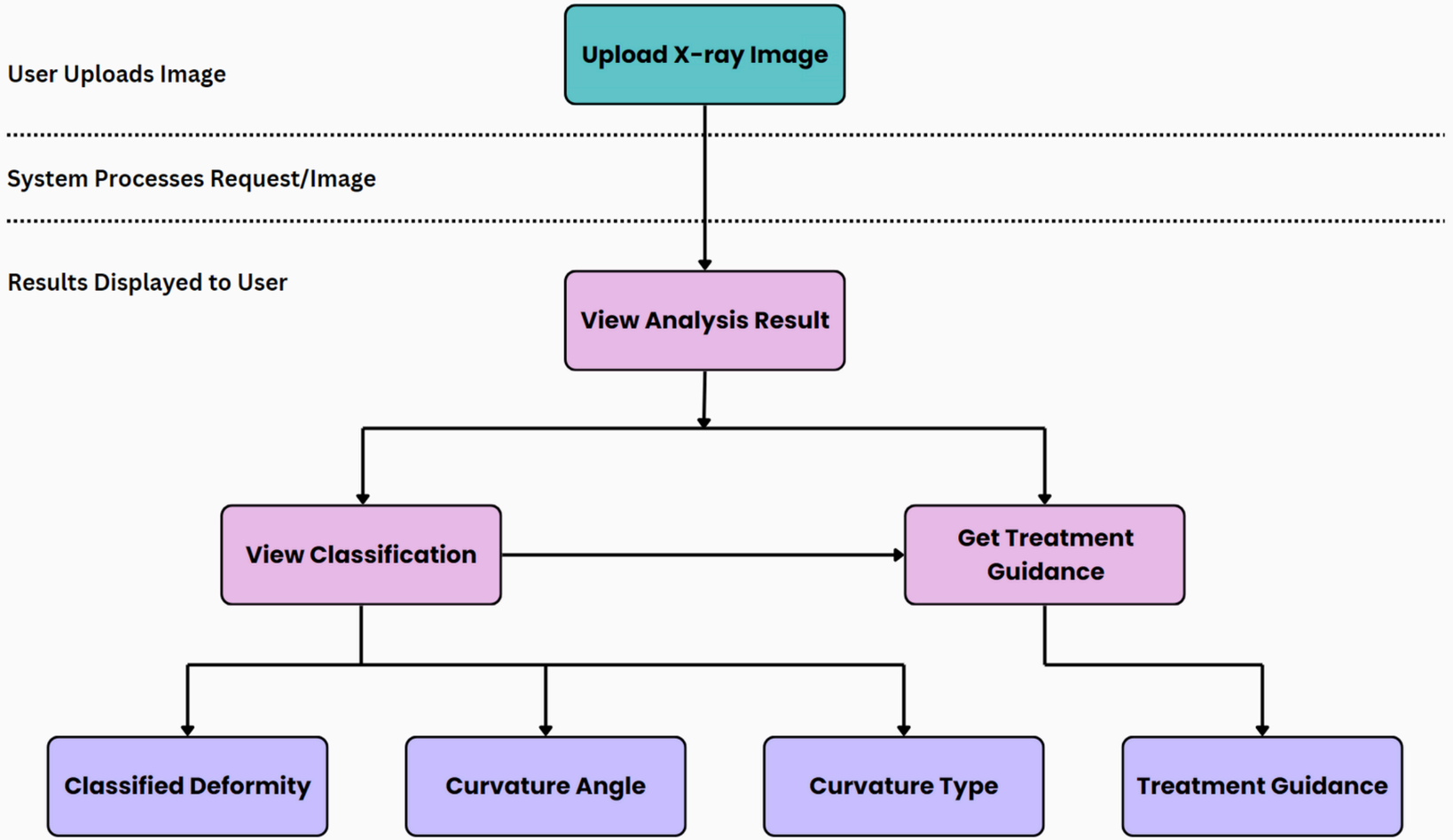
- Once scoliosis is detected, keypoints along the spine are extracted to trace its alignment.
- Using these keypoints, the Cobb’s angle is calculated by identifying the most tilted vertebrae and measuring the angle between them.
- Based on the pattern of the spinal curve, the type of curvature is classified as C-shaped or S-shaped curve.
- The severity of scoliosis is determined using Cobb’s angle measured and classifies severity into: mild, moderate, or severe.

5. POSTURE DEFORMITY DETECTION



- A labeled dataset with subfolders for lordosis, kyphosis, and neutral postures is used to train the model.
- The images are preprocessed (resized, normalized, and enhanced) to improve model accuracy and consistency.
- The trained model then detects posture deformities, including lordosis and kyphosis, from the uploaded images.
- It supports accurate diagnosis and treatment recommendations by evaluating the presence of lordosis and kyphosis.

6. TREATMENT GUIDANCE & USER INTERFACE



- Provides AI-driven treatment guidance, such as exercises and lifestyle tips for spine deformities.
- It also provides a user-friendly platform for uploading images, allowing users to easily access their results and treatment guidance in a straightforward manner.

ASSUMPTIONS

- **Sufficient Dataset Diversity:** It is assumed that the dataset includes a diverse range of spinal X-ray images, encompassing various deformities and normal cases, to ensure robust model training and accurate classification.

- **Adequate Computational Resources:** It is assumed that the project will have access to sufficient computational resources to support the training and deployment of deep learning models effectively.

WORK BREAKDOWN AND RESPONSIBILITIES

Neha Davis

Deformity Classification and Analysis

Neha Mariam Mathew

Data Collection & Preprocessing and GUI

Priya Anto

Model Development & Segmentation

Shreya Sunil

Model Optimization & Angle Measurement

HARDWARE AND SOFTWARE REQUIREMENTS

HARDWARE REQUIREMENTS	SOFTWARE REQUIREMENTS
• **GPU:** NVIDIA GPU (Tesla, Quadro, or GTX) with CUDA support (Minimum 8GB VRAM recommended). • **CPU:** Multi-core processor (Intel i7 or higher, or AMD equivalent). • **RAM:** Minimum 16GB. • **Storage:** SSD with at least 100GB free space for storing datasets and models. • **Operating System:** Linux (Ubuntu preferred) or Windows 10/11	• **OS:** Windows 10 or Ubuntu 20.04 • **Languages:** Python 3.x • **Libraries:** ◦ TensorFlow/Keras or PyTorch (ML) ◦ OpenCV (image processing) ◦ NumPy, SciPy (calculations) ◦ SciKit-Learn (classification) • **Framework:** Flask • **CUDA:** Required for GPU acceleration with TensorFlow or PyTorch.

GANTT CHART

TASKS	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR
Research & Planning								
Dataset Collection & Preprocessing								
X-ray Verification Model Training								
Scoliosis Detection								
Spine Segmentation and Curvature measurement								
Posture Deformity Detection								
User Interface & Itegration								
Testing & Documentation								

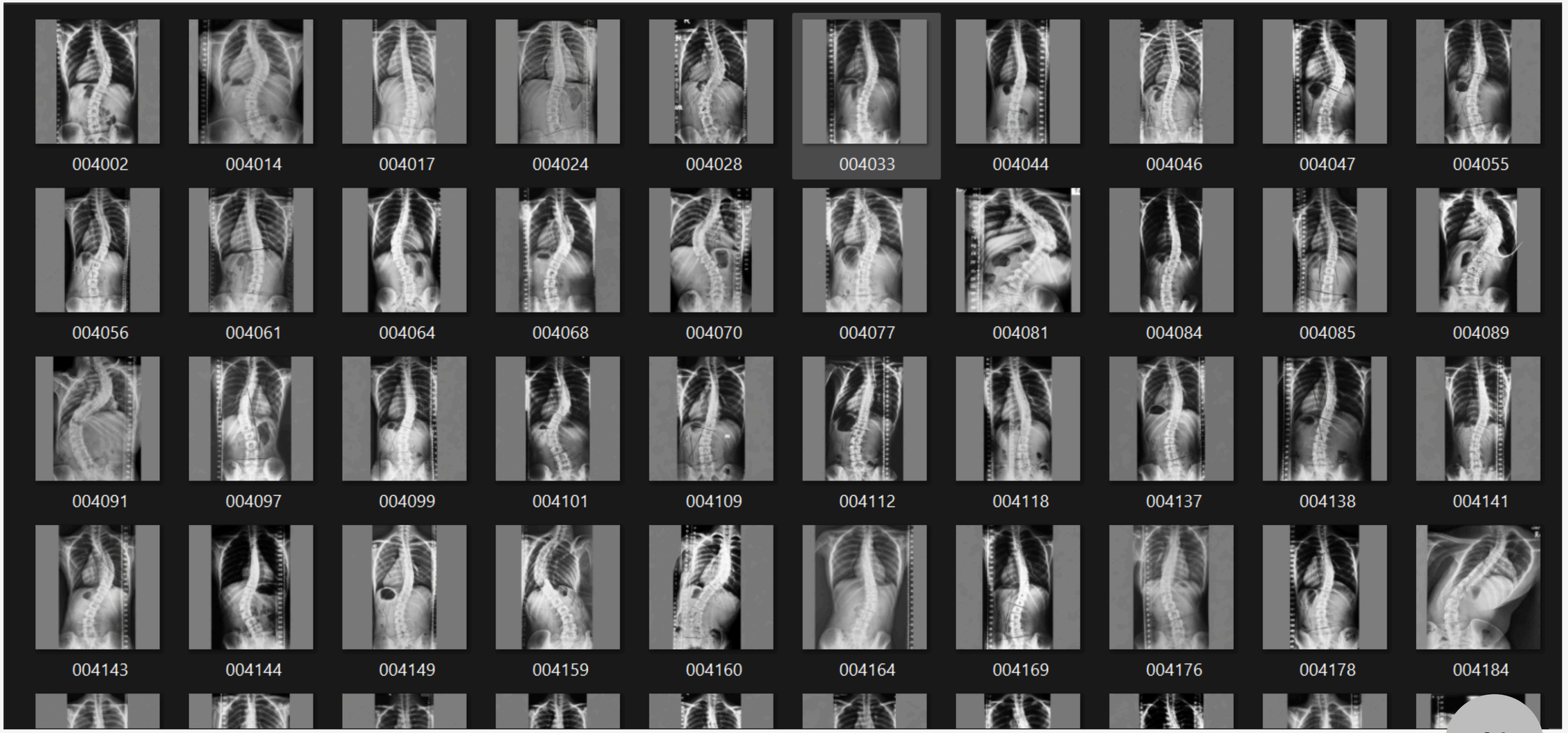
RISKS AND CHALLENGES

- **Data Quality and Availability**: Obtaining a diverse, high-quality X-ray dataset for training is challenging due to privacy issues and limited access to labeled medical data.
- **Model Accuracy and Reliability**: Achieving high accuracy is critical, as misclassifications can affect diagnosis and treatment, posing risks to patient care.
- **Integration with Existing Systems**: Integrating the system with hospital workflows and adhering to medical standards can be complex and time-consuming.
- **Adoption by Healthcare Professionals**: Gaining trust and acceptance from doctors and radiologists may be challenging, as they may prefer traditional diagnostic methods.

Scoliosis Detection Module

DATASET PREPARATION

- **Data Sources:**
  - Primary dataset from Kaggle (The vertebrae X-ray images).
  - Additional dataset manually split into scoliosis and normal categories.
- **Data Augmentation:**
  - Applied to increase and balance the distribution between normal and scoliosis classes. Augmented with `ImageDataGenerator`.
- **Data Splitting:**
  - Training: 80%
  - Validation: 10%
  - Testing: 10%
- **Purpose:**
  - Ensures a balanced dataset for effective model training and evaluation.


004002
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004178
004184

CNN MODEL

- **Preprocessing:**
  - Images resized to 224x224 and normalized.
- **Model:**
  - CNN with 3 convolutional layers, max-pooling, and fully connected layers.
  - Flattening layer
  - Output layer with softmax for multi-class classification.
- **Evaluation:**
  - Accuracy and loss on the validation set.
  - Confusion matrix visualized.
- **Visualization:**
  - Accuracy and loss plots.

OUTPUT

Browse... sol1fin.jpg

sol1fin.jpg(image/jpeg) - 275503 bytes, last modified: n/a - 100% done

Saving sollfin.jpg to sollfin.jpg

1/1 ━━━━━━━━━━━━━━━━━━━━ **0s** 49ms/step

Predicted class: Scoliosis with confidence: 100.00%

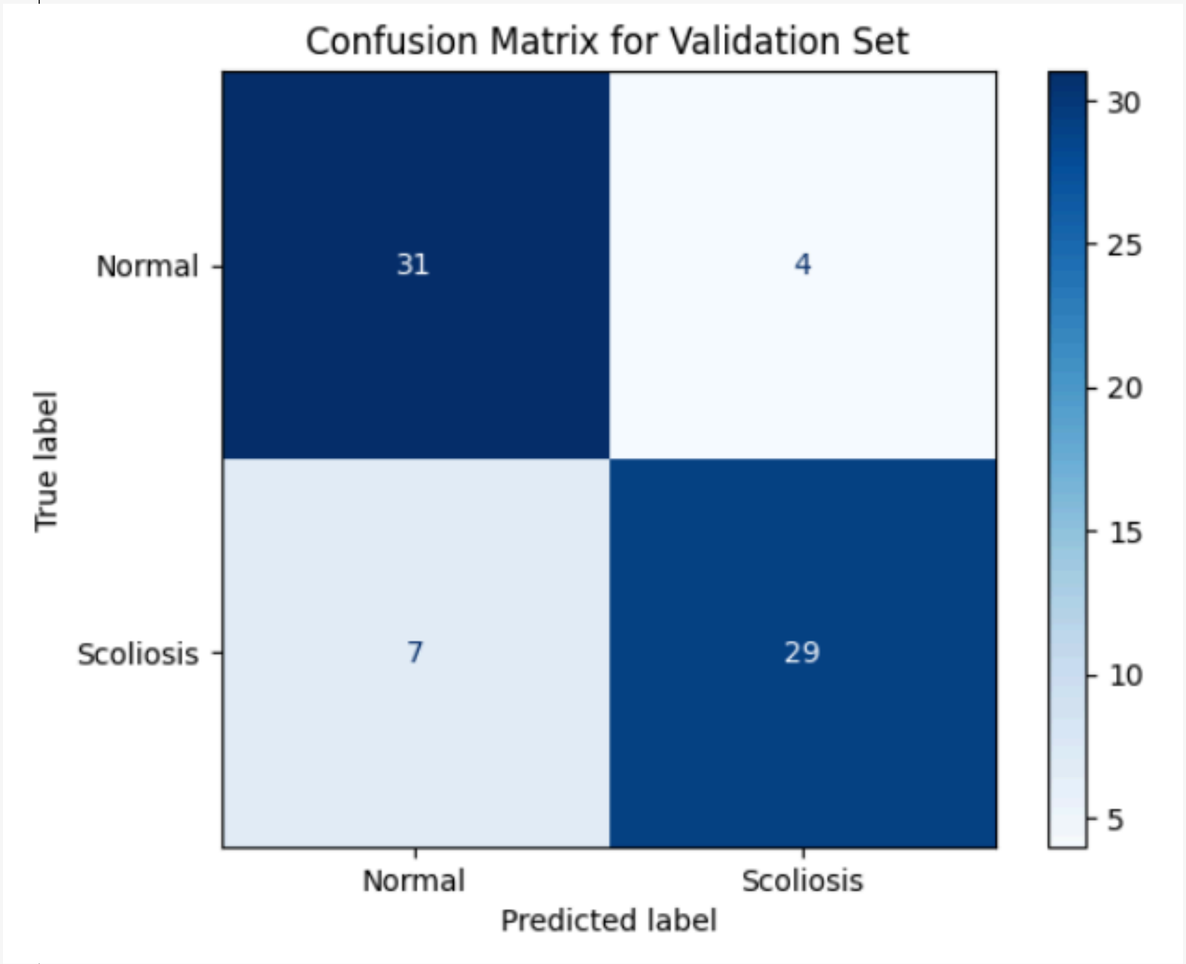
Choose Files No file chosen

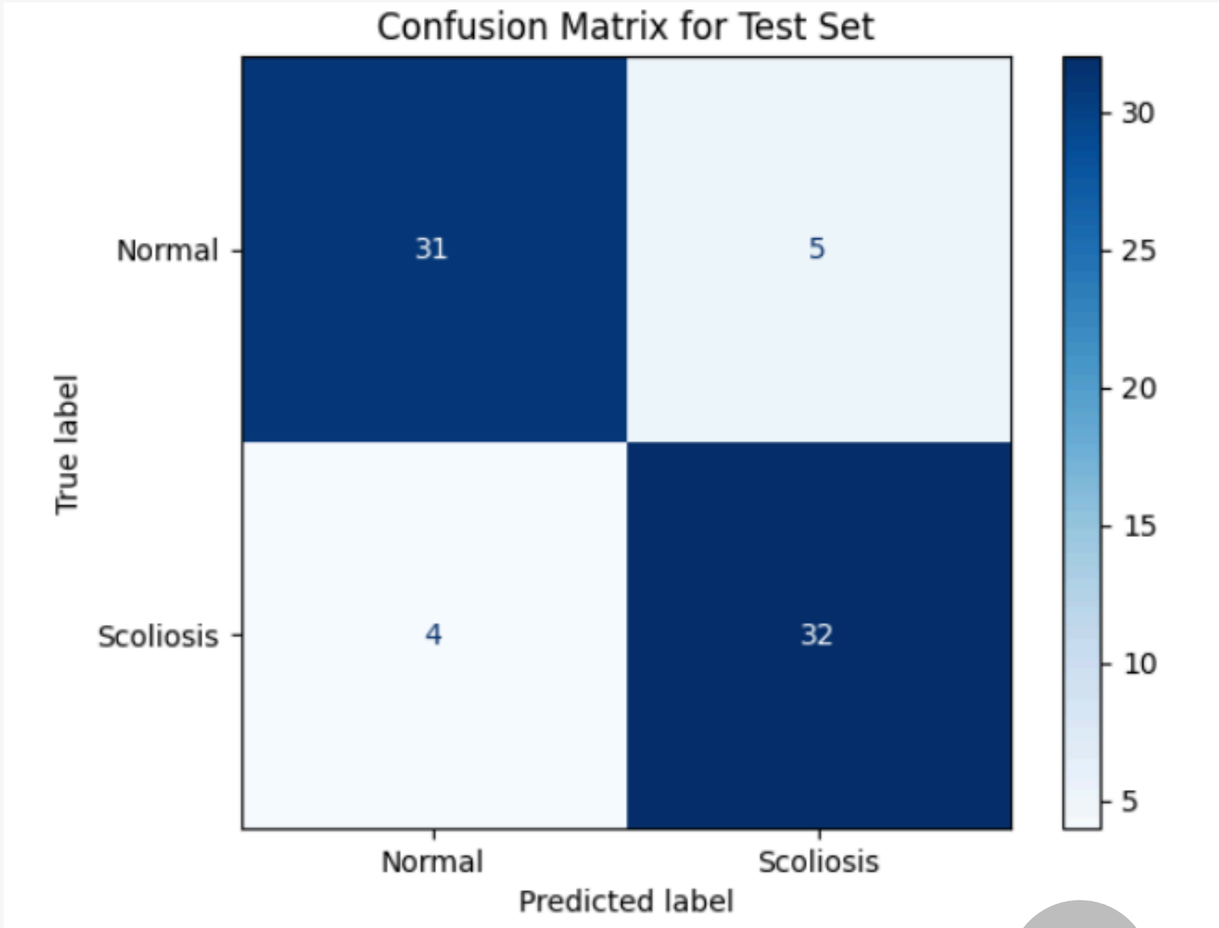
Saving normaldemo.jpg to normaldemo (1).jpg

1/1 ━━━━━━━━━━━━━━━━━━━━ **0s** 83ms/step

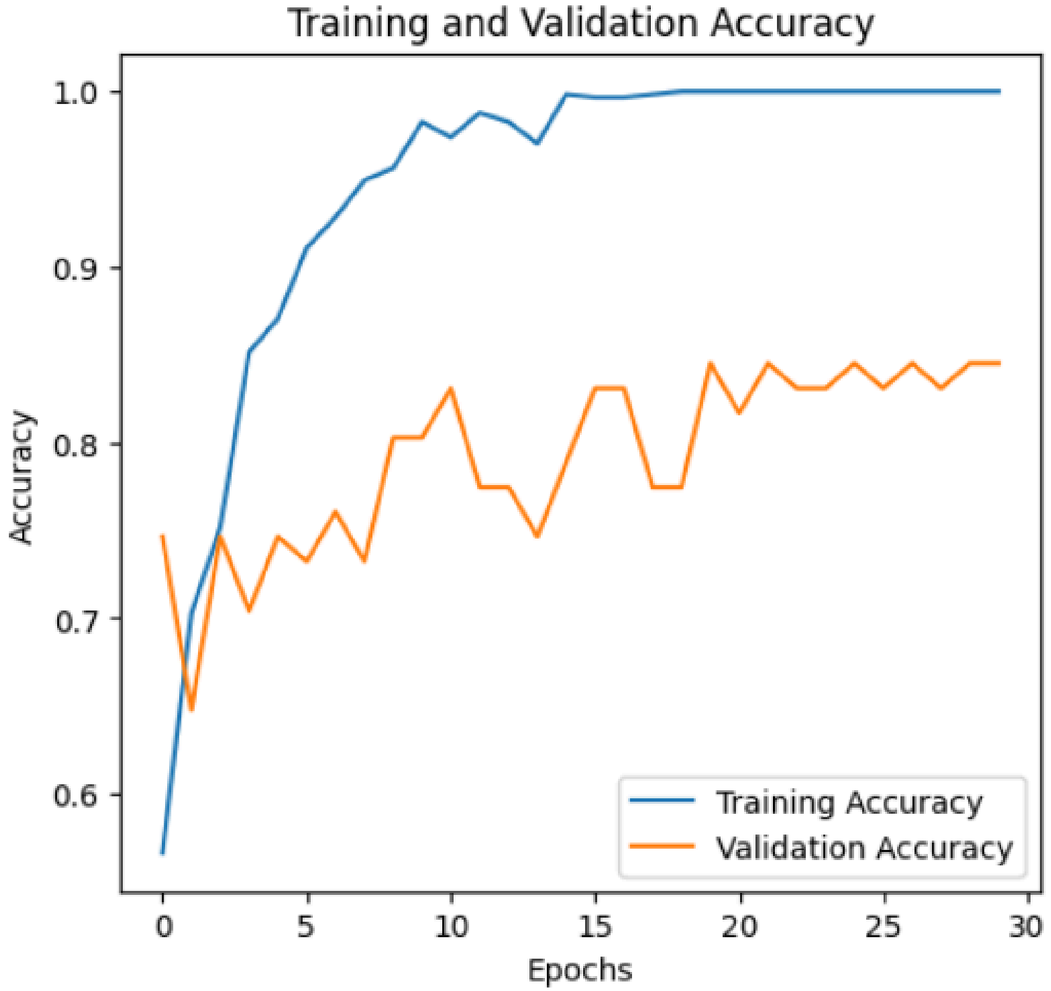
Predicted class: Normal with confidence: 100.00%

OUTPUT


Confusion Matrix for Validation Set
Normal
Scoliosis
True label
31
4
7
29
Normal
Scoliosis
Predicted label
30
25
20
15
10
5


Confusion Matrix for Test Set
Normal
Scoliosis
True label
31
5
4
32
Normal
Scoliosis
Predicted label
30
25
20
15
10
5

OUTPUT


Training and Validation Accuracy
Accuracy
Epochs
Training Accuracy
Validation Accuracy


Training and Validation Loss
Loss
Epochs
Training Loss
Validation Loss

TRANSFER LEARNING

- **Model Architecture:**
  - Base: InceptionV3 (pre-trained).
  - Custom layers: GlobalAveragePooling, Dense, Dropout, Sigmoid for binary classification.
- **Training:**
  - Optimizer: Adam, Loss: binary cross-entropy, Metric: accuracy.
  - Callbacks: EarlyStopping and ModelCheckpoint.
- **Evaluation:**
  - Test accuracy and loss.
  - Classification report and confusion matrix.
- **Visualization:**
  - Accuracy/loss plots, confusion matrix heatmap.

OUTPUT

```
[32]    # Plot the image with the prediction
        img = image.load_img(img_path, target_size=(224, 224))  # Reload image for display
        plt.imshow(img)
        plt.title(f"Prediction: {'Scoliosis' if predicted_class[0][0] == 1 else 'Normal'}")
        plt.axis('off')
        plt.show()
```

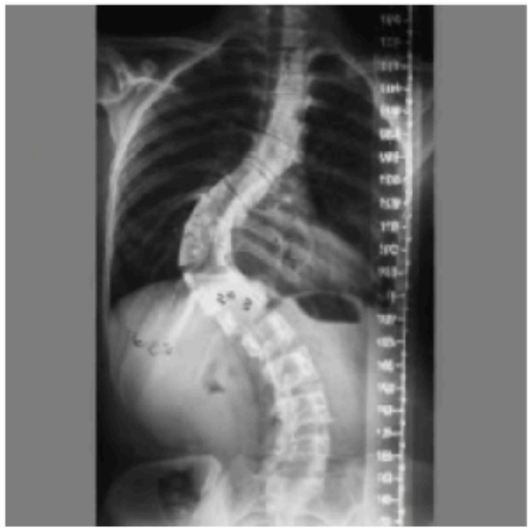
```
Choose Files No file chosen
Saving 000011.jpg to 000011 (1).jpg
1/1 ━━━━━━━━━━━━━━━━━━━━ 3s 3s/step
The model predicts: Normal
```

Prediction: Normal

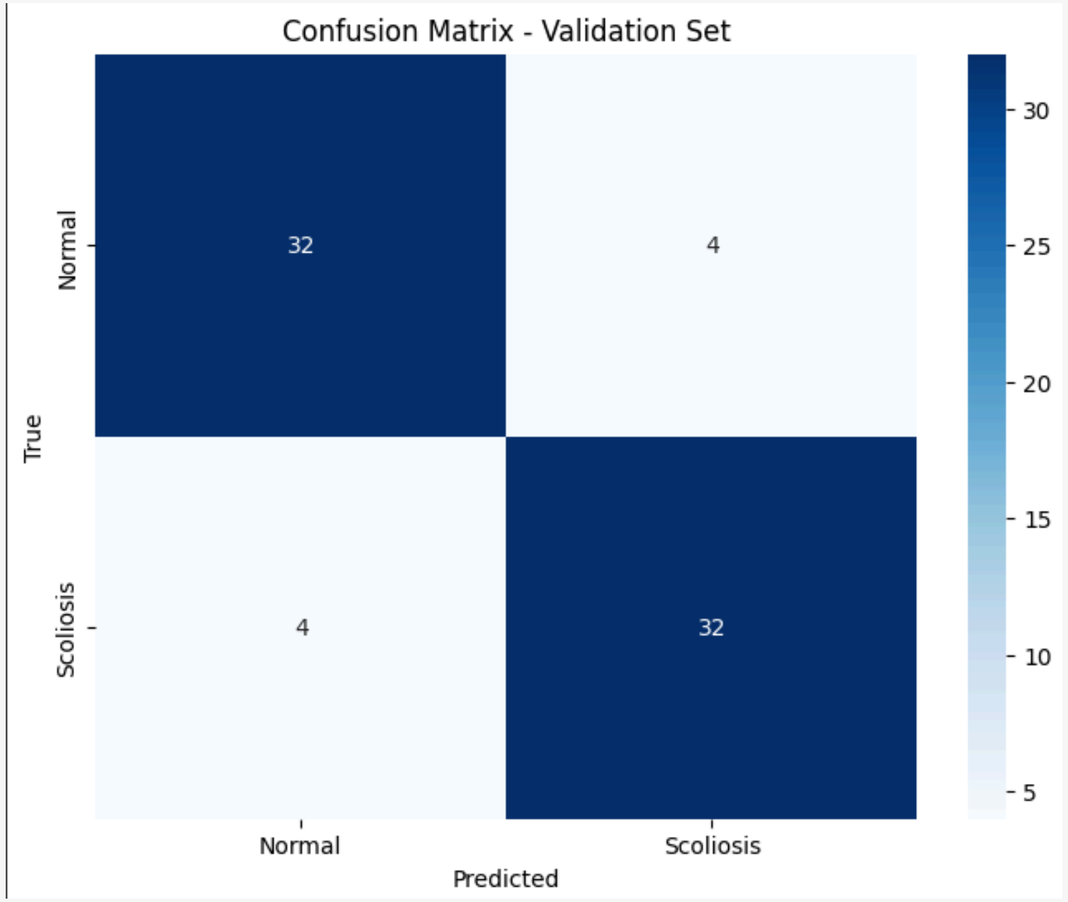
```
plt.imshow(img)
plt.title(f"Prediction: {'Scoliosis' if predicted_class[0][0] == 1 else 'Normal'}")
plt.axis('off')
plt.show()
```

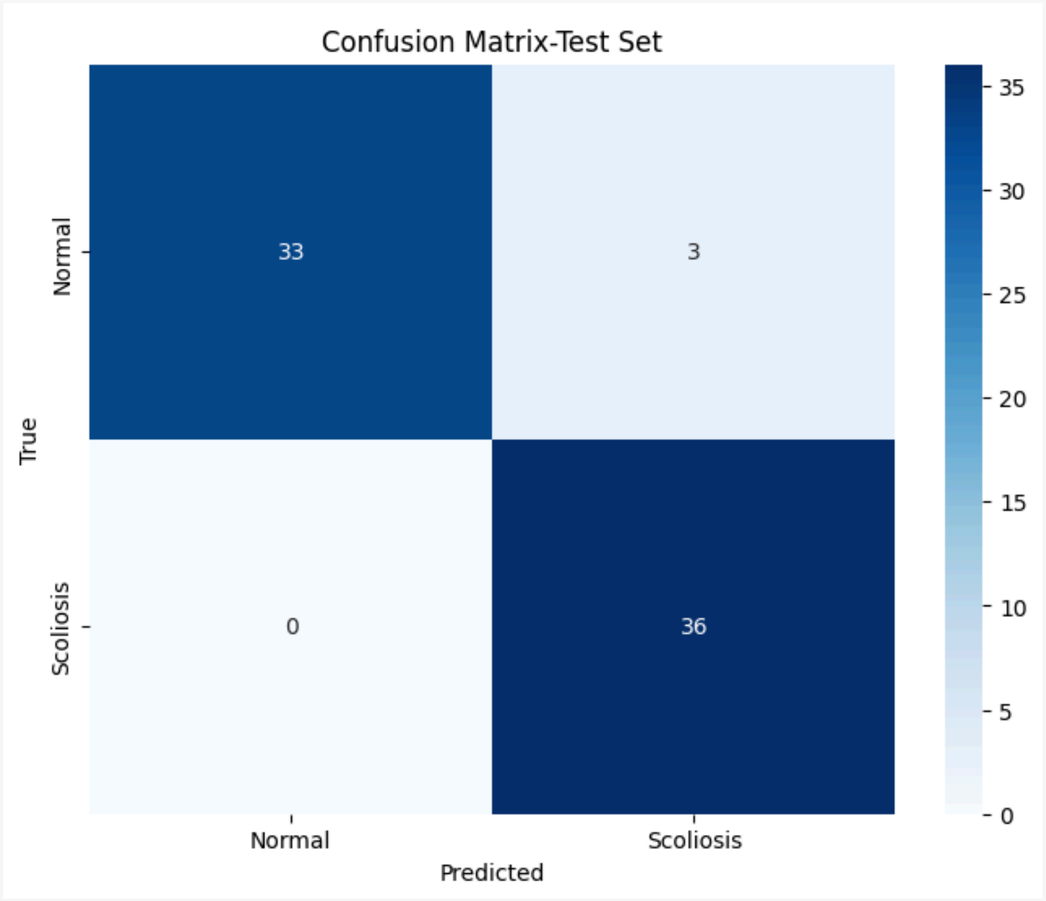
```
Choose Files No file chosen
Saving 000019.jpg to 000019.jpg
1/1 ━━━━━━━━━━━━━━━━━━━━ 4s 4s/step
The model predicts: Scoliosis
```

Prediction: Scoliosis

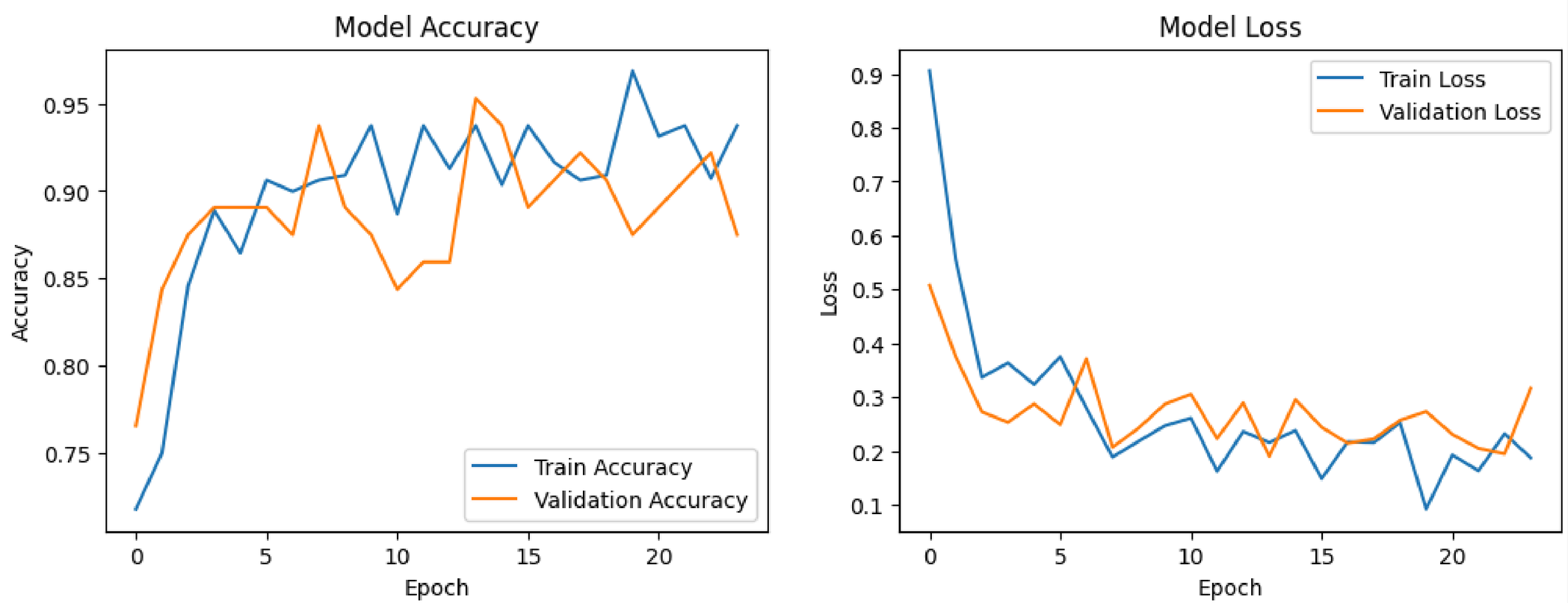


OUTPUT

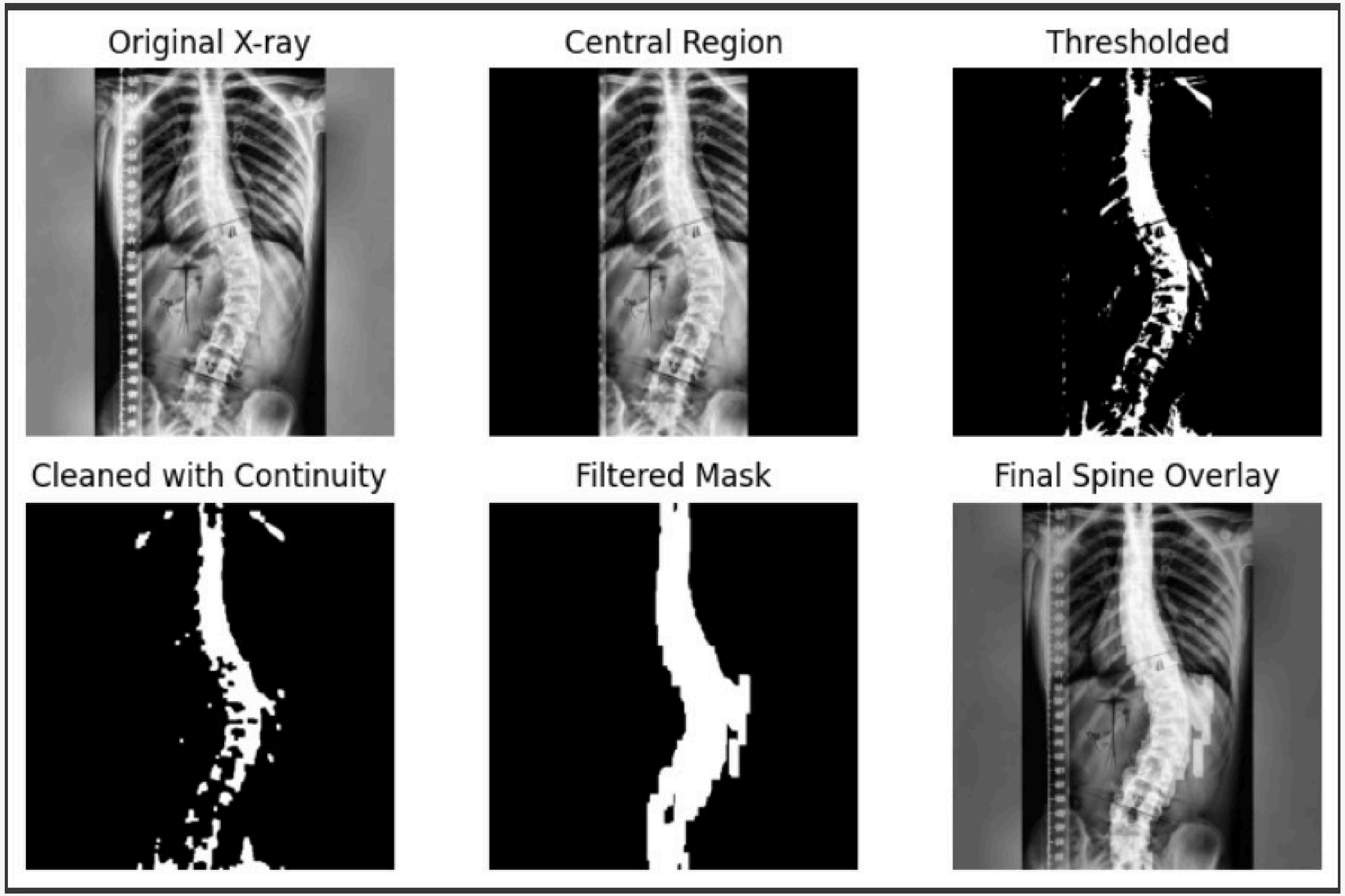

Confusion Matrix - Validation Set
Normal
Scoliosis
True
32
4
4
32
Normal
Scoliosis
Predicted
30
25
20
15
10
5


Confusion Matrix-Test Set
Normal
Scoliosis
True
33
3
0
36
Normal
Scoliosis
Predicted
35
30
25
20
15
10
5
0

OUTPUT


Model Accuracy
Accuracy
Epoch
Train Accuracy
Validation Accuracy
0.95
0.90
0.85
0.80
0.75
0
5
10
15
20
Model Loss
Loss
Epoch
Train Loss
Validation Loss
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1

SPINE SEGMENTATION



SPINE SEGMENTATION

1. **Preprocessing and Thresholding**: The central region of the X-ray is focused on using a vertical mask, followed by intensity thresholding to isolate the spine.

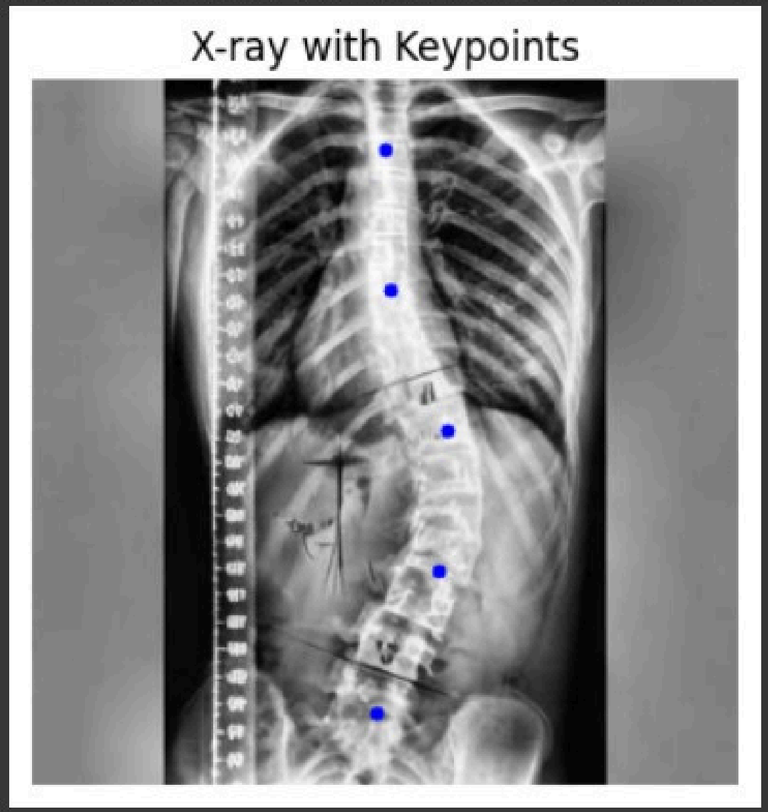
2. **Morphological Operations**: Noise is removed, and fragmented parts of the spine are connected using morphological operations, ensuring continuity.

3. **Gap Filling and Dilation**: Gaps in the spine are filled, and dilation connects distant spine regions to capture the full structure.

4. **Component Filtering and Final Masking**: Small irrelevant components are filtered out, and the refined mask isolates the spine, which is then overlaid on the original image for better visualization.

GENERATING KEY POINTS ALONG THE MASK

```
Keypoints (centered horizontally in each region): [(256, 51), (260, 153), (301, 255), (295, 357), (250, 460)]
```



COBB ANGLE MEASUREMENT AND SEVERITY CLASSSIFICATION

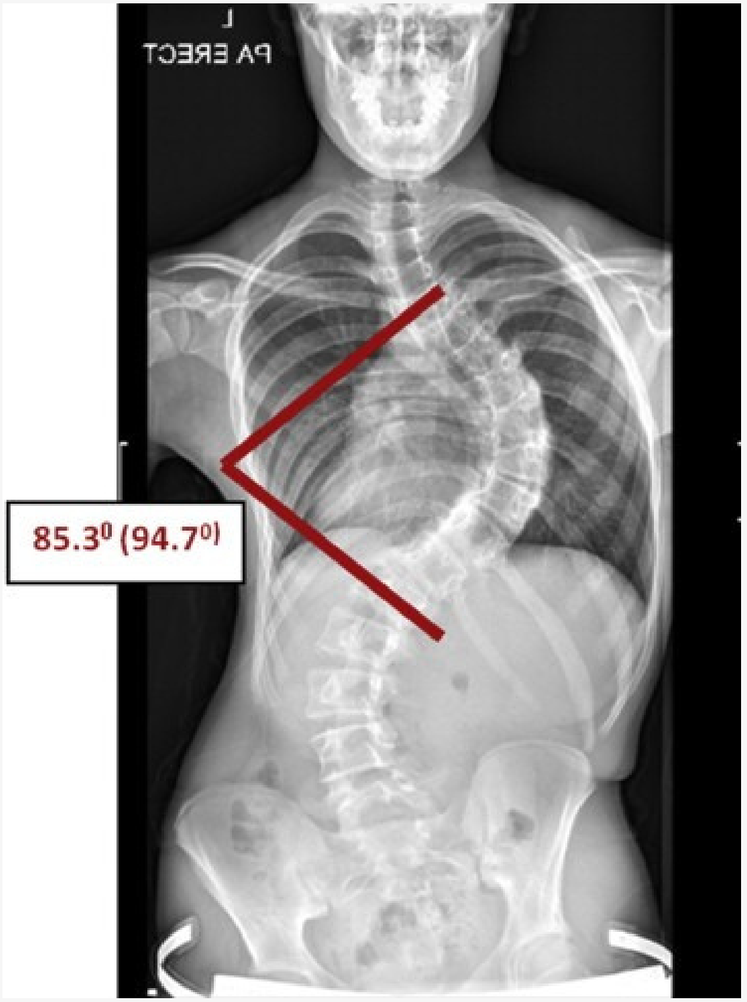
1. **Click to Select Points**: Users click on five vertebrae points in the uploaded image to help accurately calculate the Cobb angle.

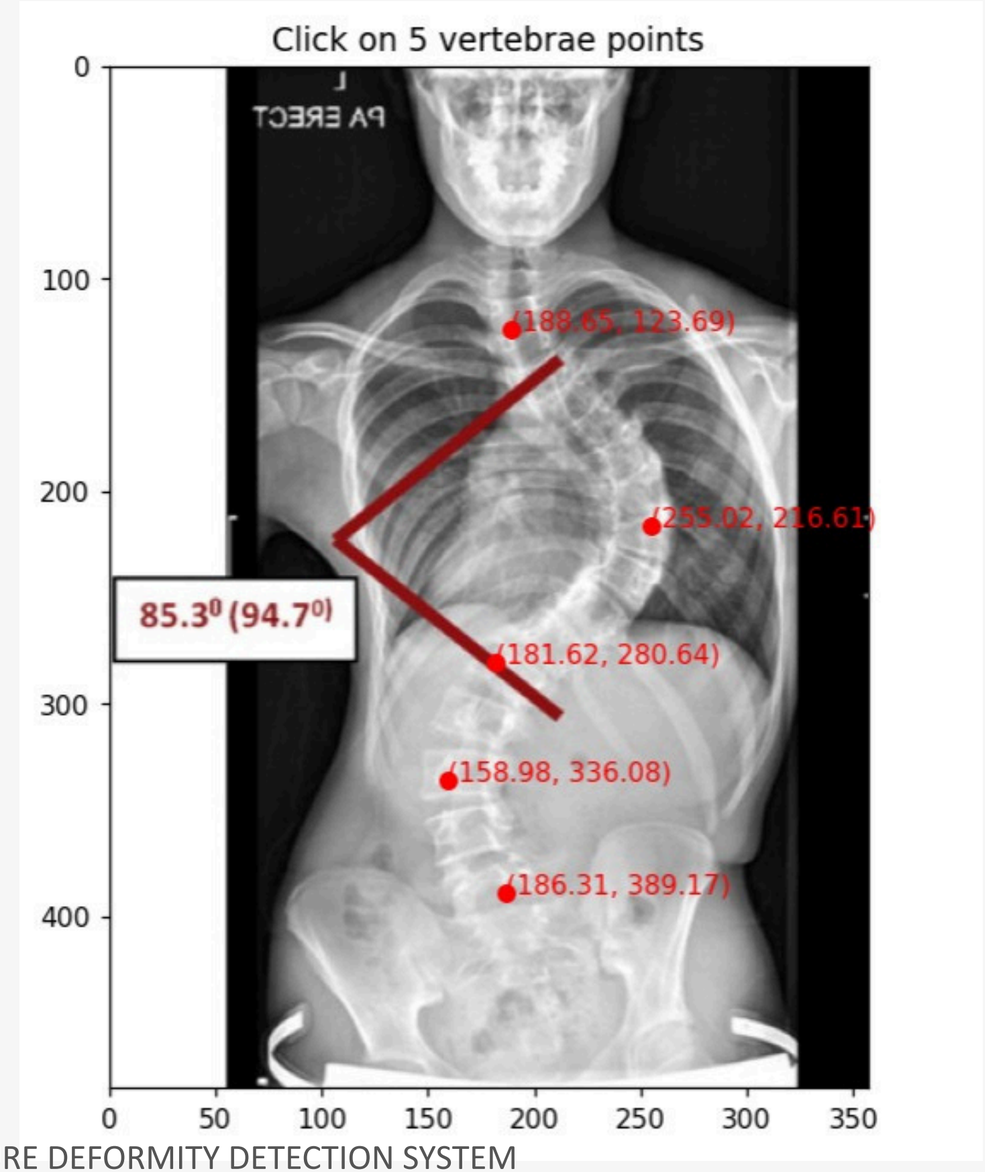
2. **Cobb Angle Calculation**: The code computes the Cobb angle from the selected points.

3. **Curve Classification**: Based on the Cobb angle, the curve is classified as S-shaped or C-shaped.

4. **Severity Assessment**: The severity of scoliosis (mild, moderate, or severe) is determined with treatment recommendations.

COBB ANGLE MEASUREMENT FOR A S-CURVE

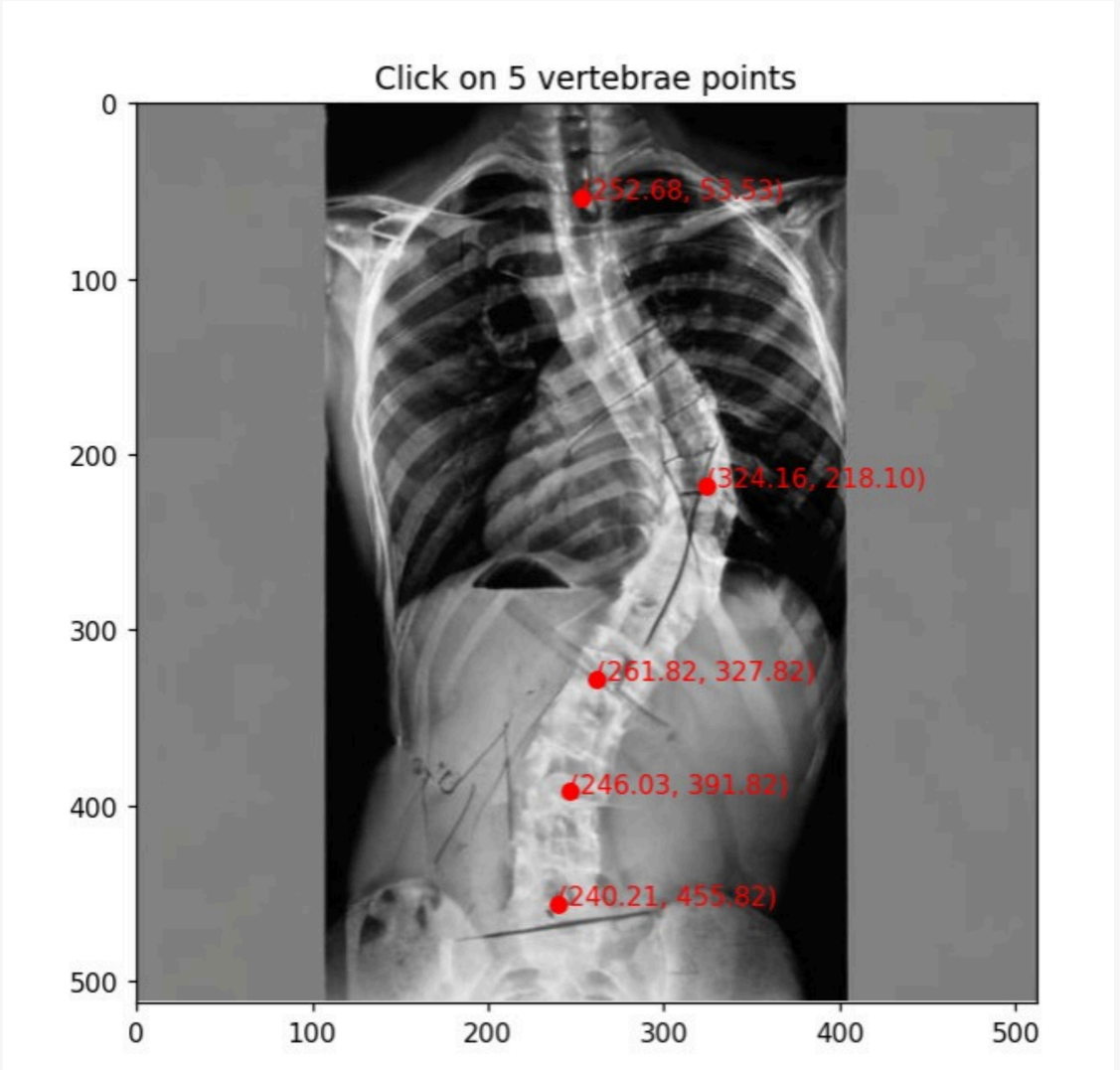




COBB ANGLE AND SEVERITY CLASSSIFICATION FOR A S-SHAPED CURVE

```
Clicked: (188.65, 123.69)
Clicked: (255.02, 216.61)
Clicked: (181.62, 280.64)
Clicked: (158.98, 336.08)
Clicked: (186.31, 389.17)
Five points clicked. Processing Cobb Angle...
Top Cobb Angle: 84.44°
Bottom Cobb Angle: 49.45°
Maximum Cobb Angle: 84.44°
Curve Type: S-shaped curve
Severity:
Severe scoliosis: Cobb angle of more than 40 degrees.
Spinal fusion surgery may be required to correct the curve.
```

COBB ANGLE MEASUREMENT FOR A C-CURVE

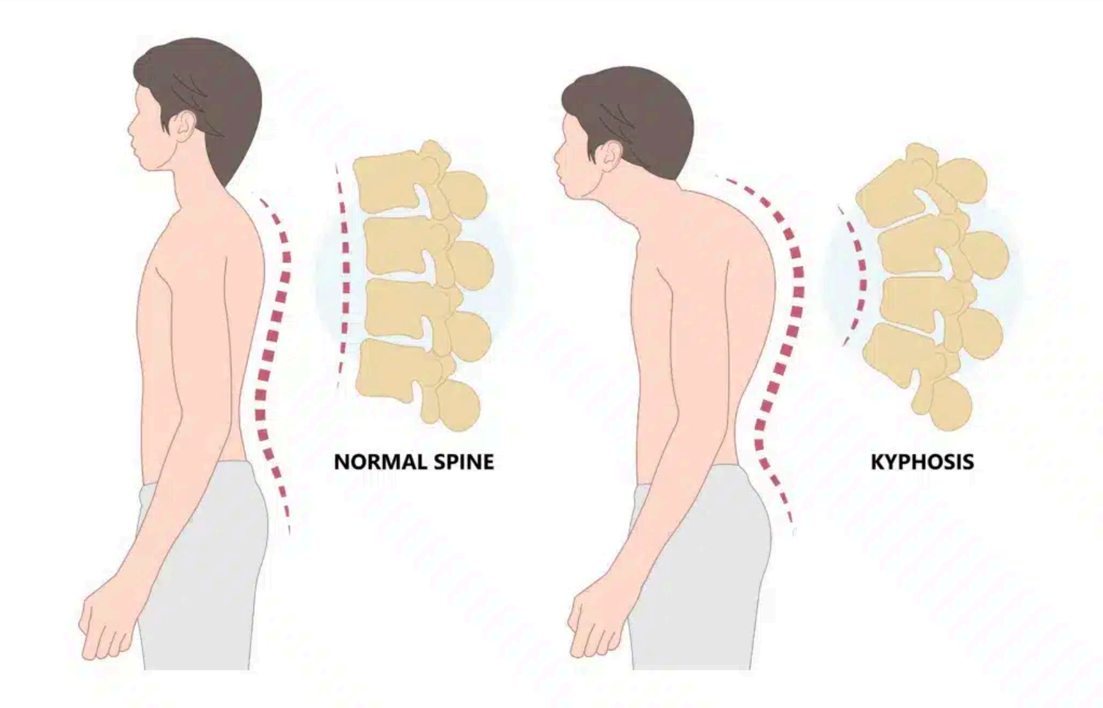


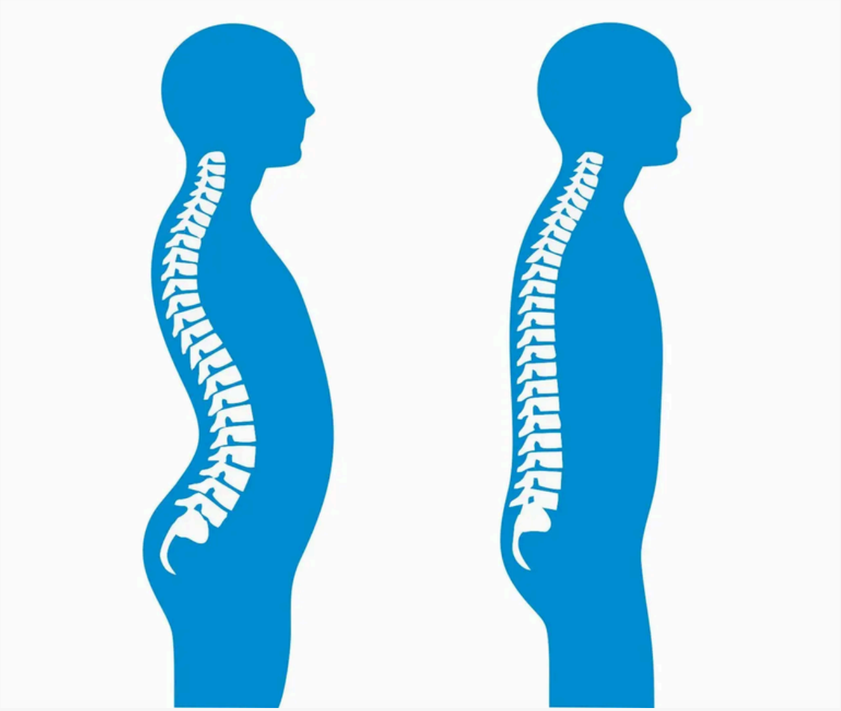
COBB ANGLE AND SEVERITY CLASSSIFICATION FOR A C-SHAPED CURVE

```
Clicked: (252.68, 53.53)
Clicked: (324.16, 218.10)
Clicked: (261.82, 327.82)
Clicked: (246.03, 391.82)
Clicked: (240.21, 455.82)
Five points clicked. Processing Cobb Angle...
Top Cobb Angle: 53.08°
Bottom Cobb Angle: 8.67°
Maximum Cobb Angle: 53.08°
Curve Type: C-shaped curve
Severity:
Severe scoliosis: Cobb angle of more than 40 degrees.
Spinal fusion surgery may be required to correct the curve.
```

Posture Deformity Detection Module

WHAT IS KYPHOSIS & LORDOSIS?





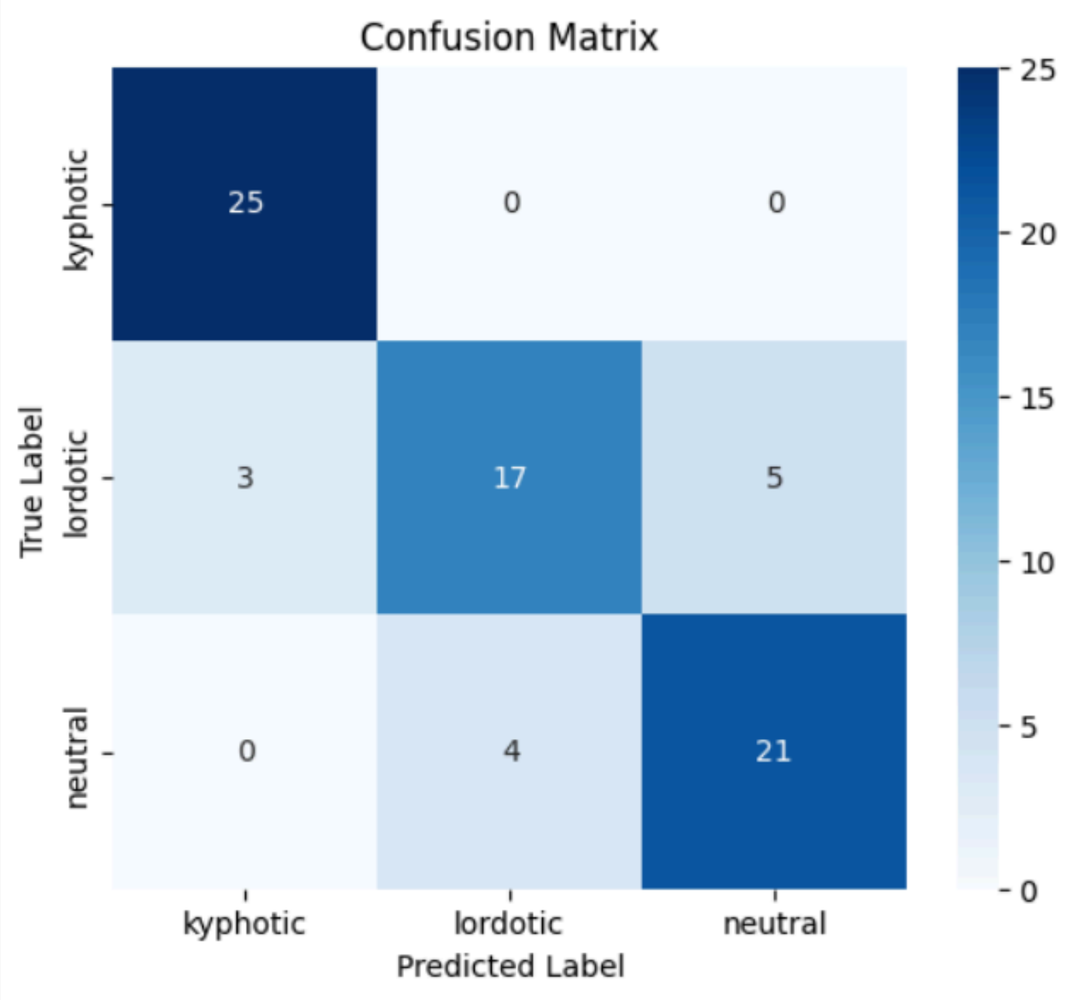
MODEL WORKFLOW

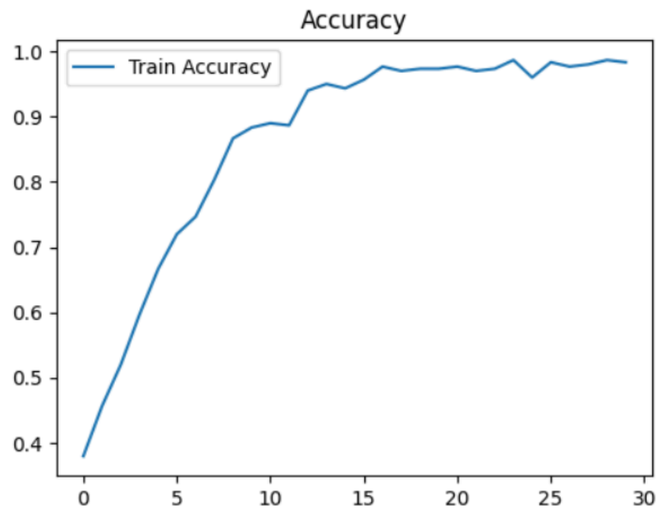
- **Data Preprocessing & Augmentation**
  - Loads images from /content/LordKyph with rotation, shift, zoom, flip.
  - Splits dataset: 80% training, 20% validation.
- **Model Architecture**
  - Base Model: EfficientNetB0 (pre-trained, frozen weights).
    - Added Layers:Global Average Pooling
    - Dense (128, ReLU) → Dropout (0.5)
    - Dense (3, Softmax) → 3-class classification.

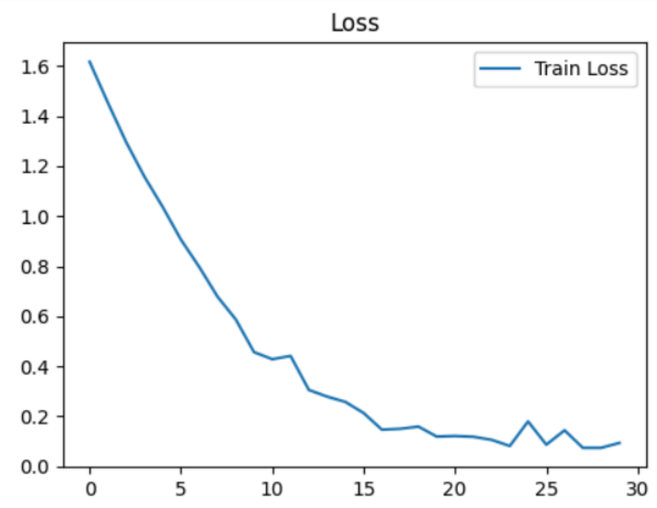
TRAINING & EVALUATION

- **Compilation & Training**
  - Optimizer: Adam
  - Loss Function: Categorical Crossentropy
  - Metric: Accuracy
  - Trained for 30 epochs on augmented data.
- **Model Saving, Testing & Evaluation**
  - Saves model as lordkyph_classifier.h5.
  - Loads saved model for evaluation.
  - Tests on a separate dataset & prints test accuracy.
  - Plots accuracy & loss curves for performance analysis.

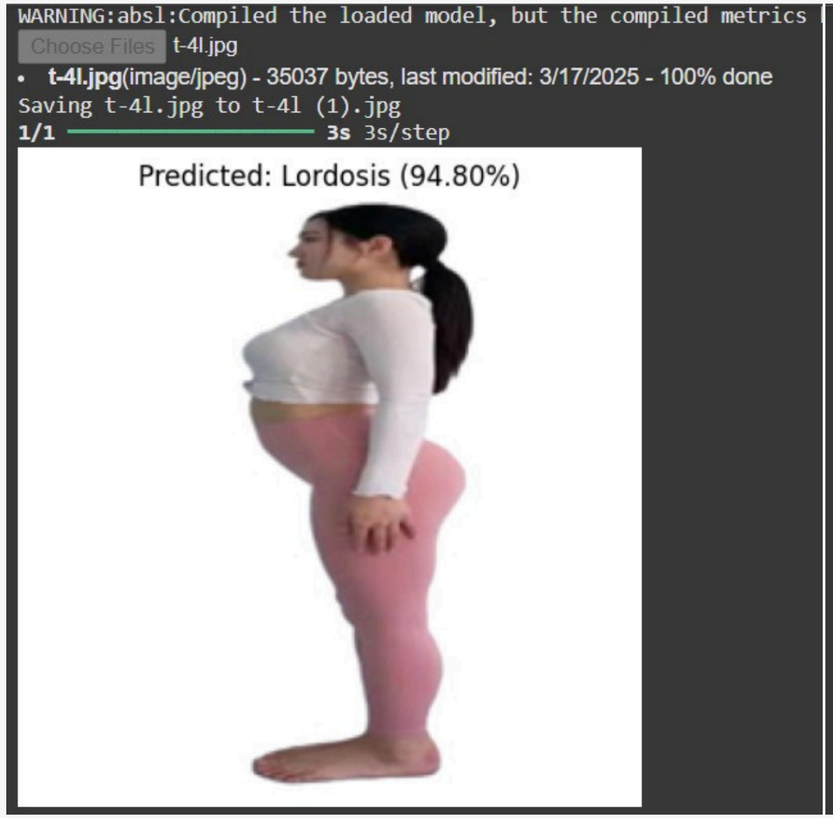
OUTPUT


Confusion Matrix
kyphotic
lordotic
neutral
True Label
25
0
0
3
17
5
0
4
21
kyphotic
lordotic
neutral
Predicted Label
25
20
15
10
5
0

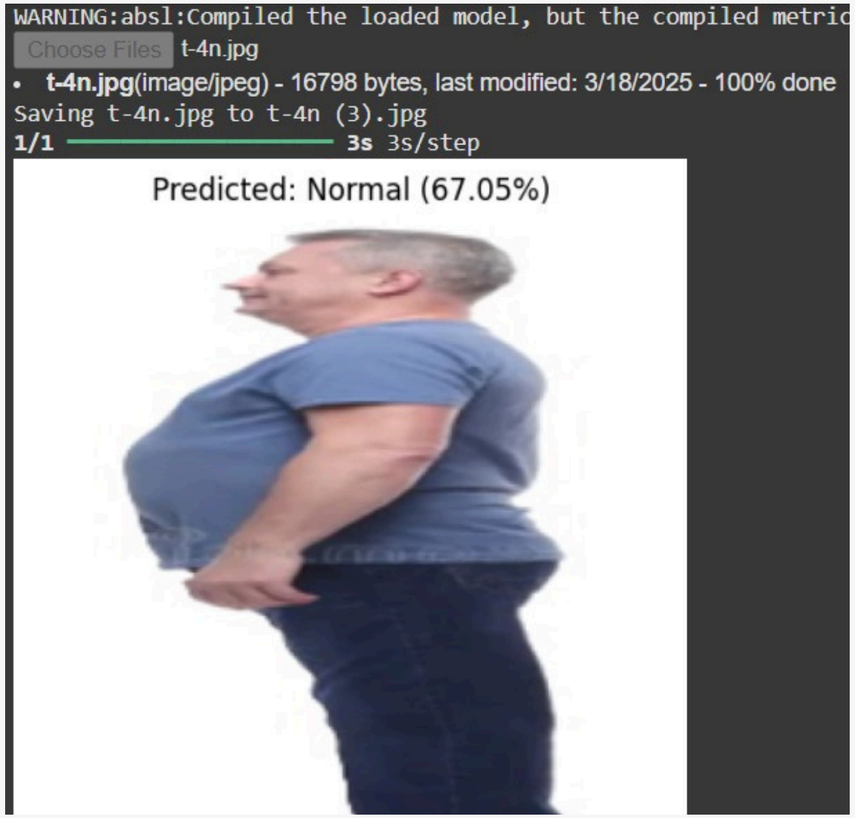

Accuracy
Train Accuracy
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0
5
10
15
20
25
30


Loss
Train Loss
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
5
10
15
20
25
30

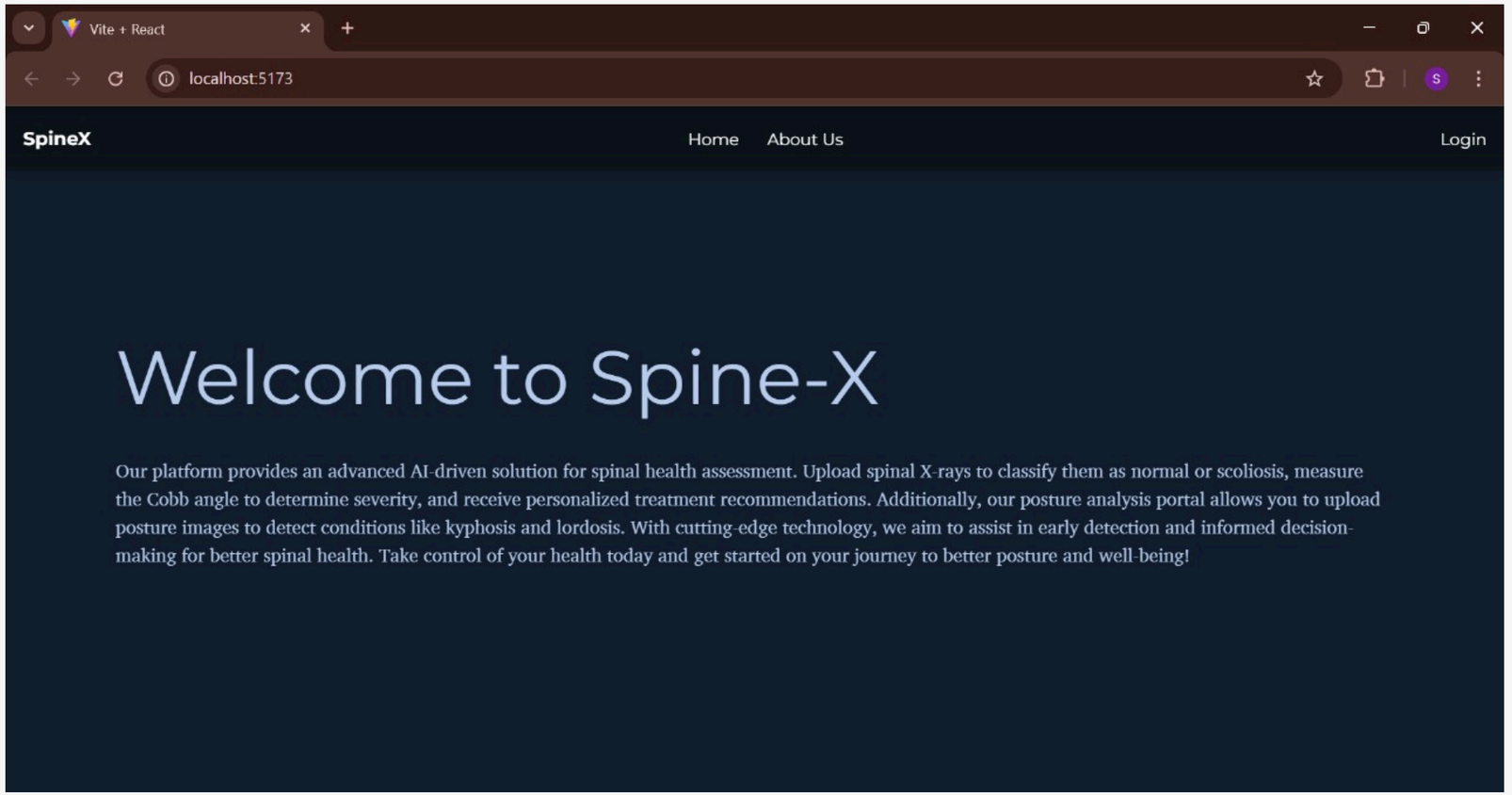
OUTPUT

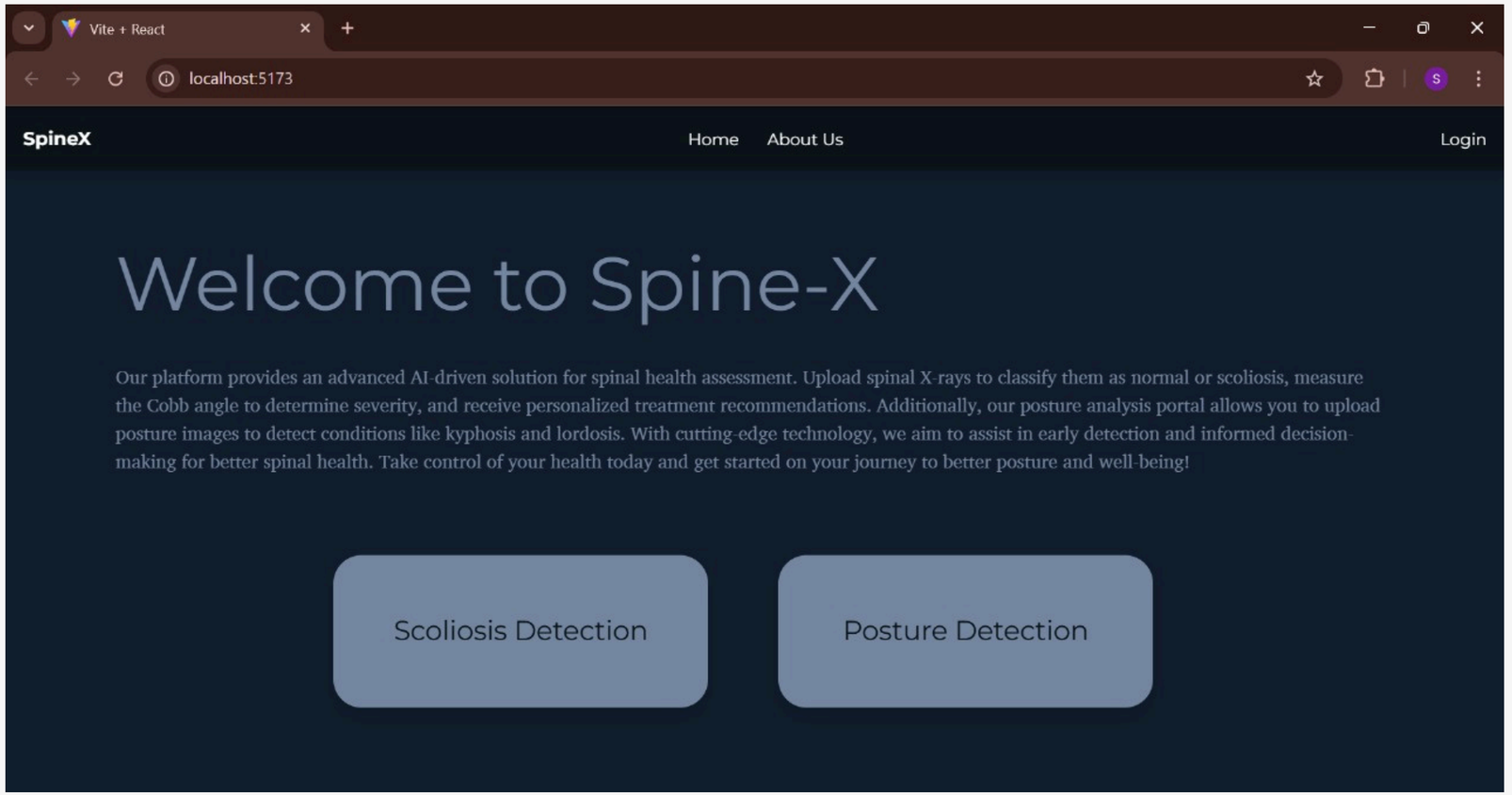

WARNING:absl:Compiled the loaded model, but the compiled metrics
Choose Files t-4l.jpg
t-4l.jpg(image/jpeg) - 35037 bytes, last modified: 3/17/2025 - 100% done
Saving t-4l.jpg to t-4l (1).jpg
1/1 3s 3s/step
Predicted: Lordosis (94.80%)


WARNING:absl:Compiled the loaded model, but the compiled metric
Choose Files t-lk.jpg
t-lk.jpg(image/jpeg) - 17447 bytes, last modified: 3/17/2025 - 100% done
Saving t-lk.jpg to t-lk (2).jpg
1/1 3s 3s/step
Predicted: Kyphosis (69.61%)


WARNING:absl:Compiled the loaded model, but the compiled metric
Choose Files t-4n.jpg
t-4n.jpg(image/jpeg) - 16798 bytes, last modified: 3/18/2025 - 100% done
Saving t-4n.jpg to t-4n (3).jpg
1/1 3s 3s/step
Predicted: Normal (67.05%)

User Interfaces


Vite + React
localhost:5173
SpineX
Home
About Us
Login
Welcome to Spine-X
Our platform provides an advanced AI-driven solution for spinal health assessment. Upload spinal X-rays to classify them as normal or scoliosis, measure the Cobb angle to determine severity, and receive personalized treatment recommendations. Additionally, our posture analysis portal allows you to upload posture images to detect conditions like kyphosis and lordosis. With cutting-edge technology, we aim to assist in early detection and informed decision-making for better spinal health. Take control of your health today and get started on your journey to better posture and well-being!


Vite + React
localhost:5173
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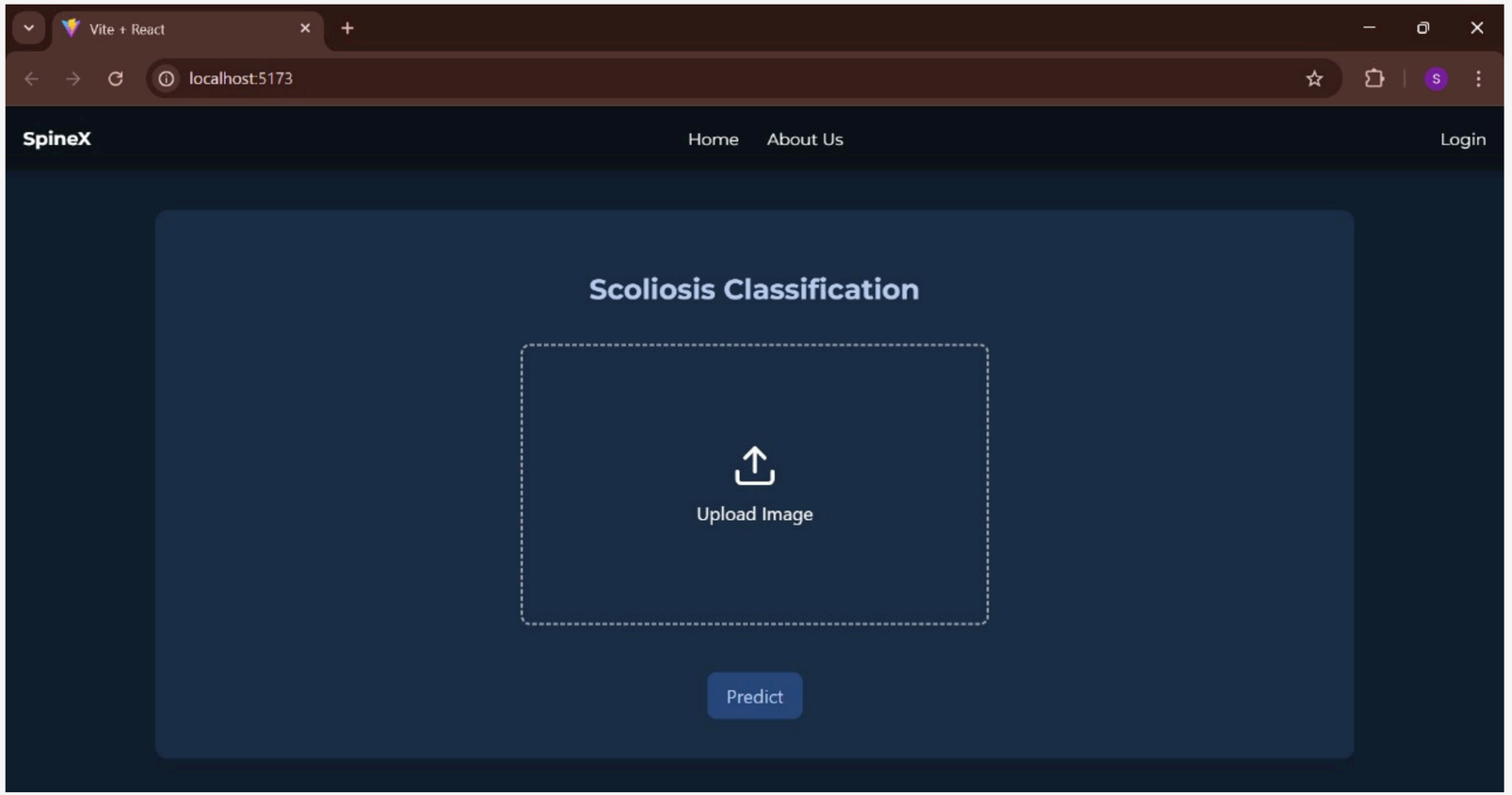
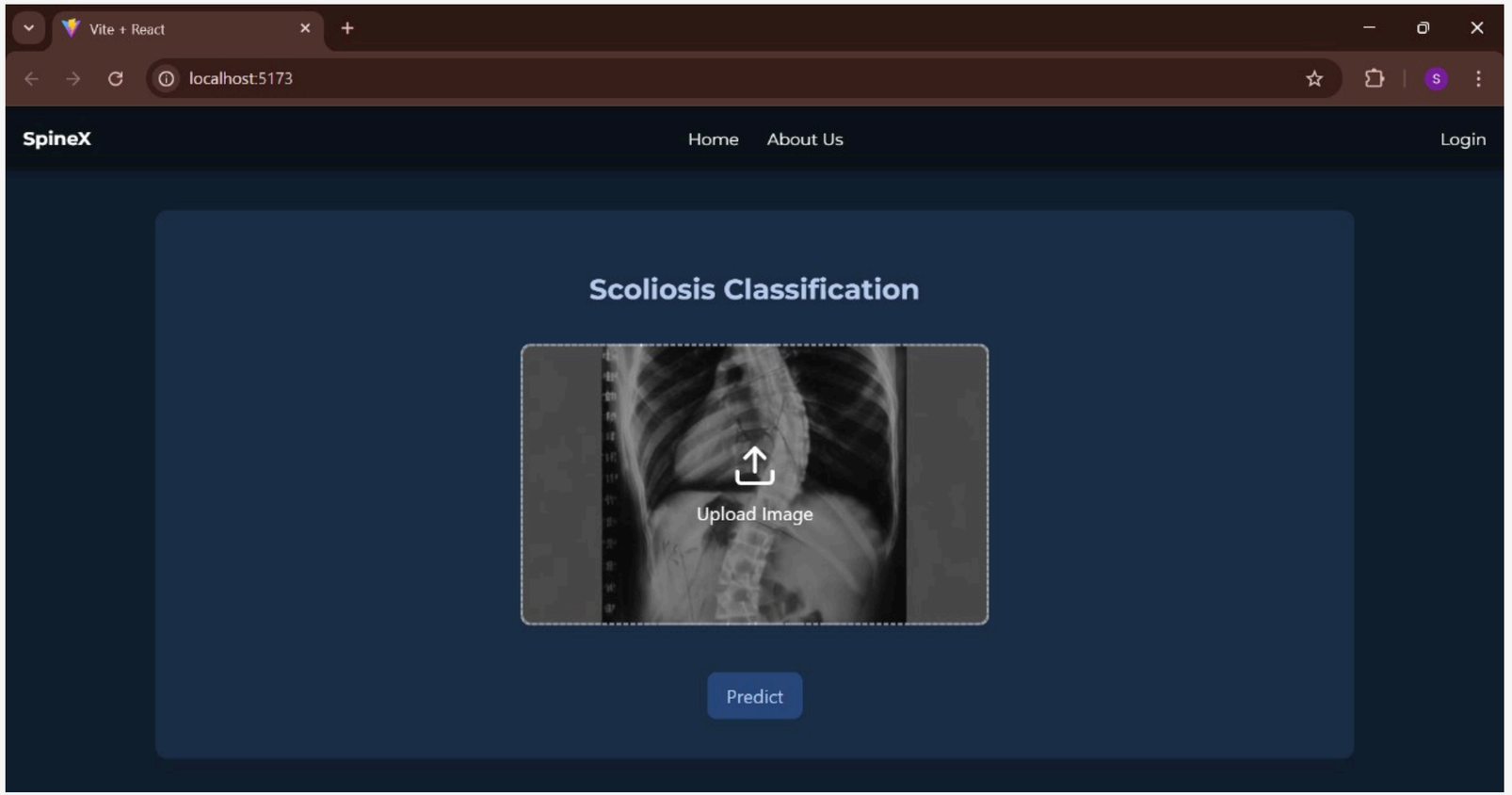
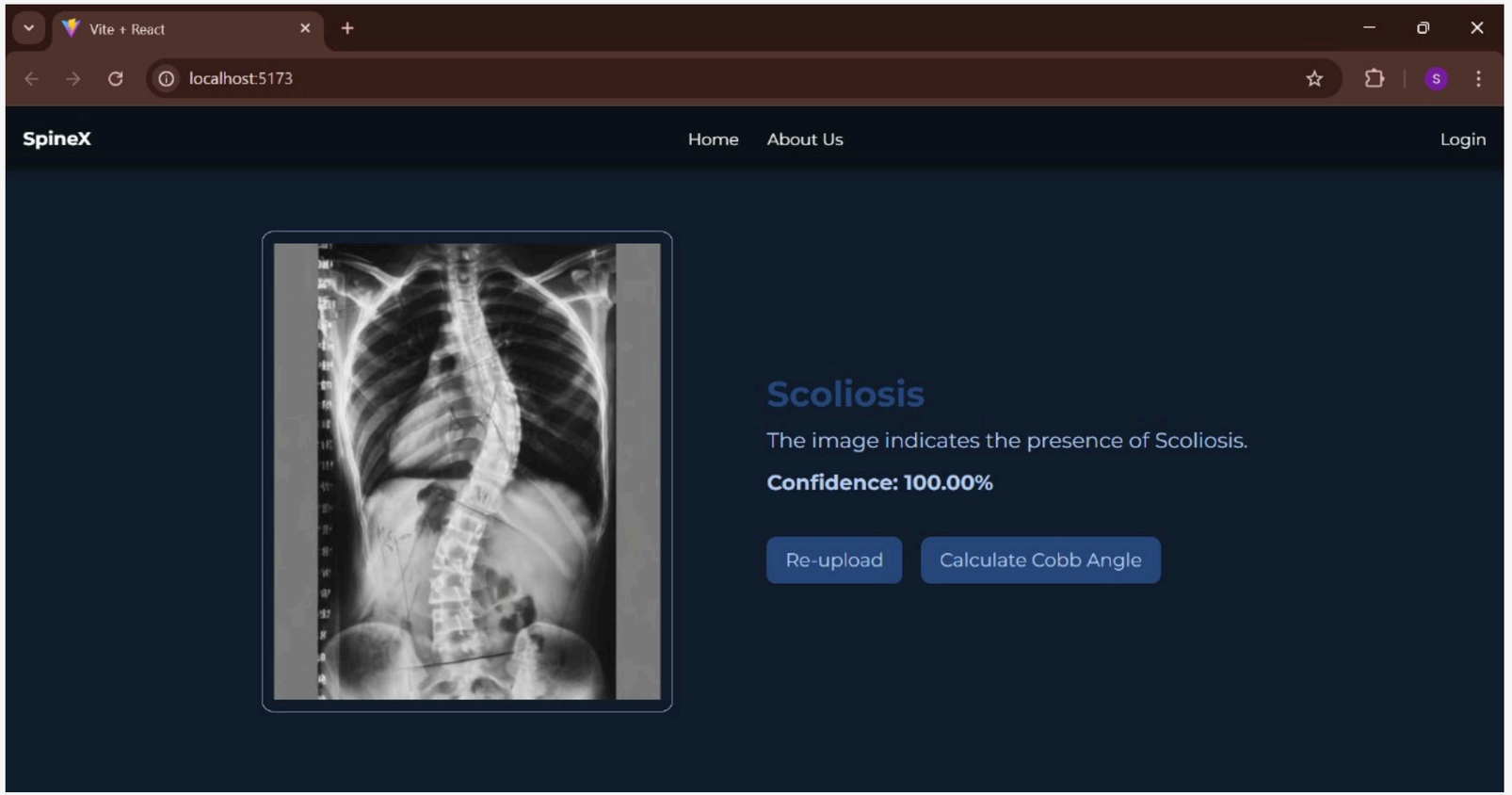
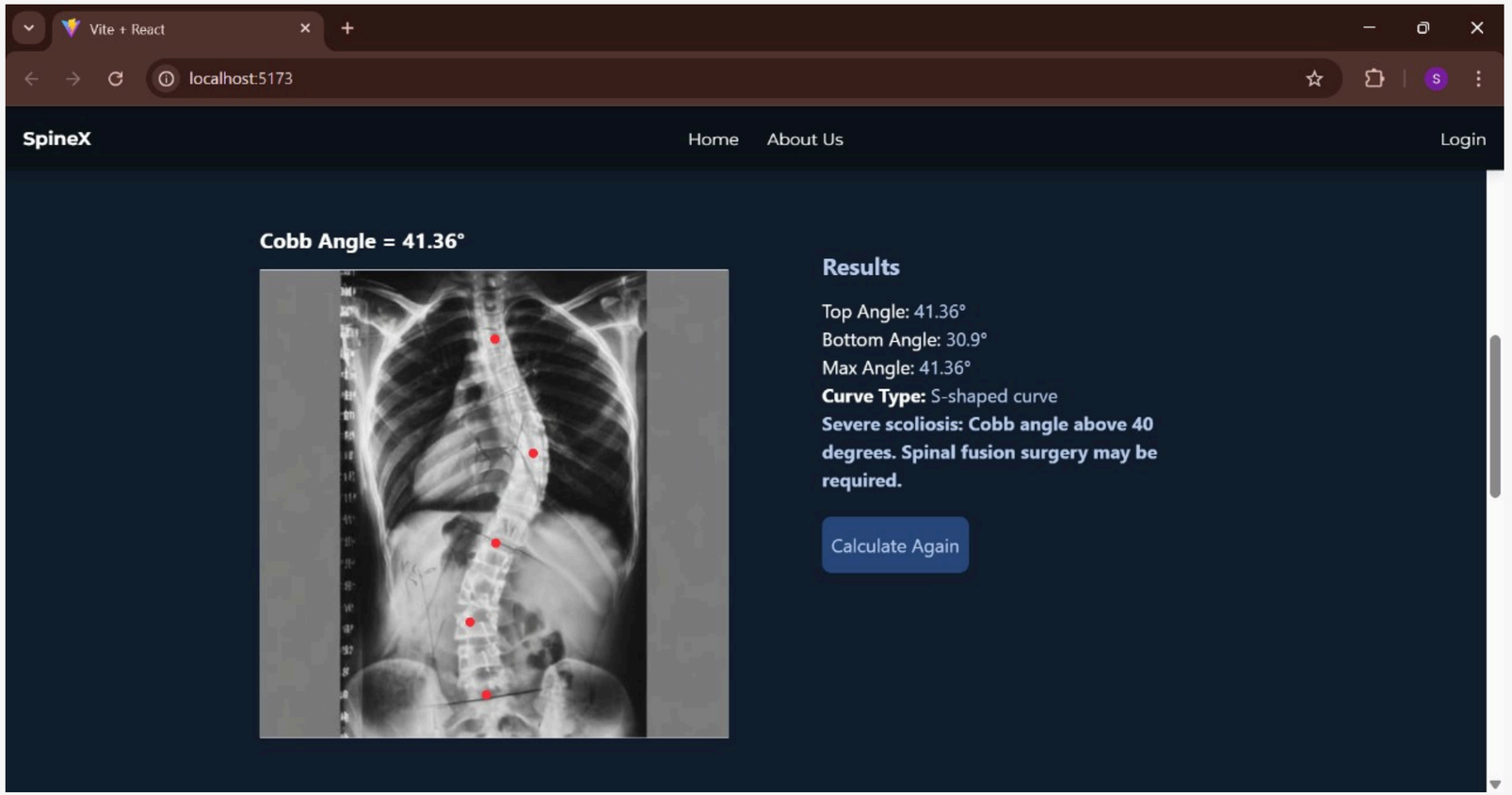
Scoliosis Detection
Posture Detection


Vite + React
localhost:5173
SpineX
Home
About Us
Login
Scoliosis Classification
Upload Image
Predict


Vite + React
localhost:5173
SpineX
Home
About Us
Login
Scoliosis Classification
Upload Image
Predict


Vite + React
localhost:5173
SpineX
Home
About Us
Login
Scoliosis
The image indicates the presence of Scoliosis.
Confidence: 100.00%
Re-upload
Calculate Cobb Angle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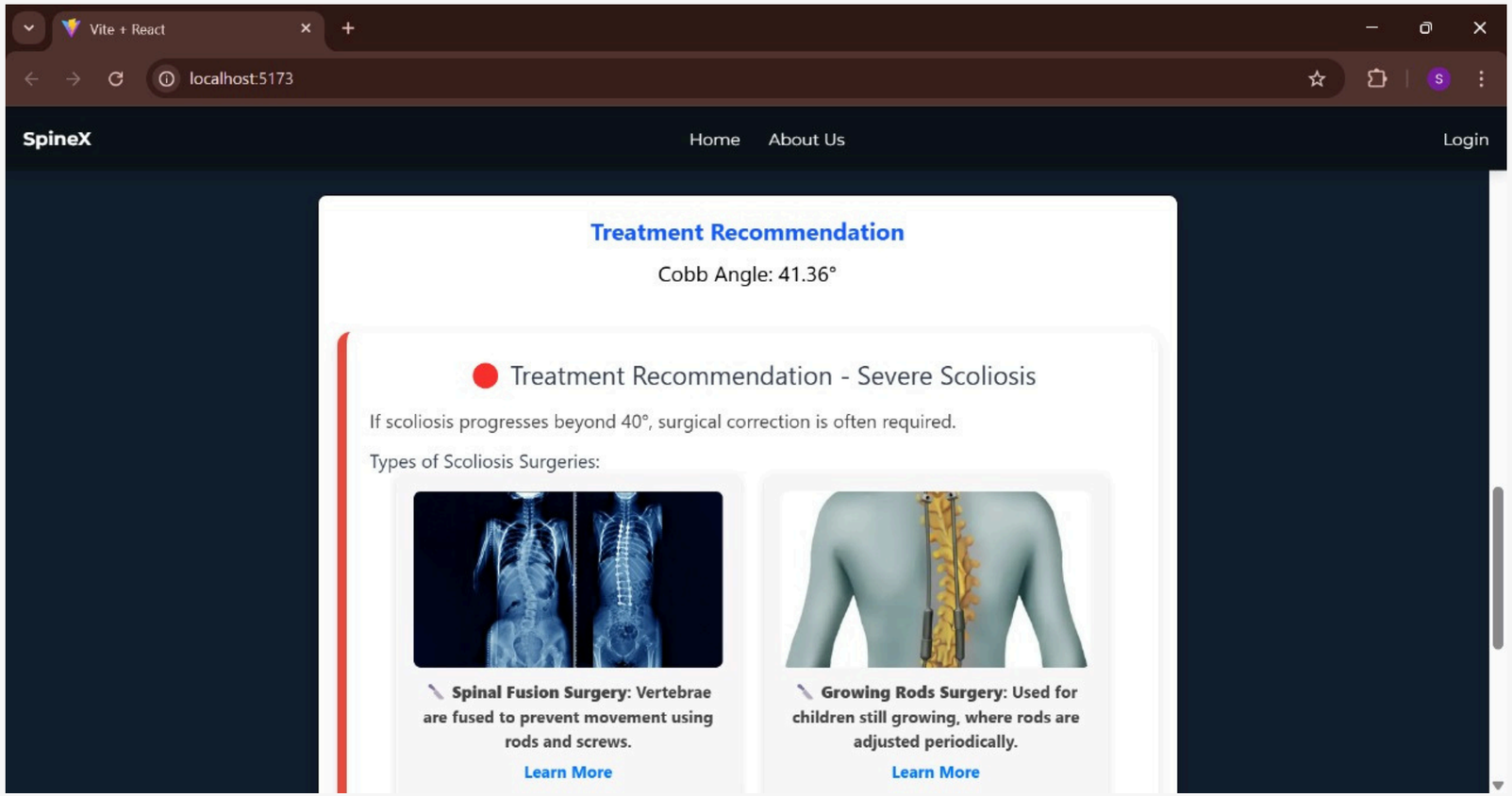
Cobb Angle = 41.36°
Results
Top Angle: 41.36°
Bottom Angle: 30.9°
Max Angle: 41.36°
Curve Type: S-shaped curve
Severe scoliosis: Cobb angle above 40 degrees. Spinal fusion surgery may be required.
Calculate Again


Vite + React
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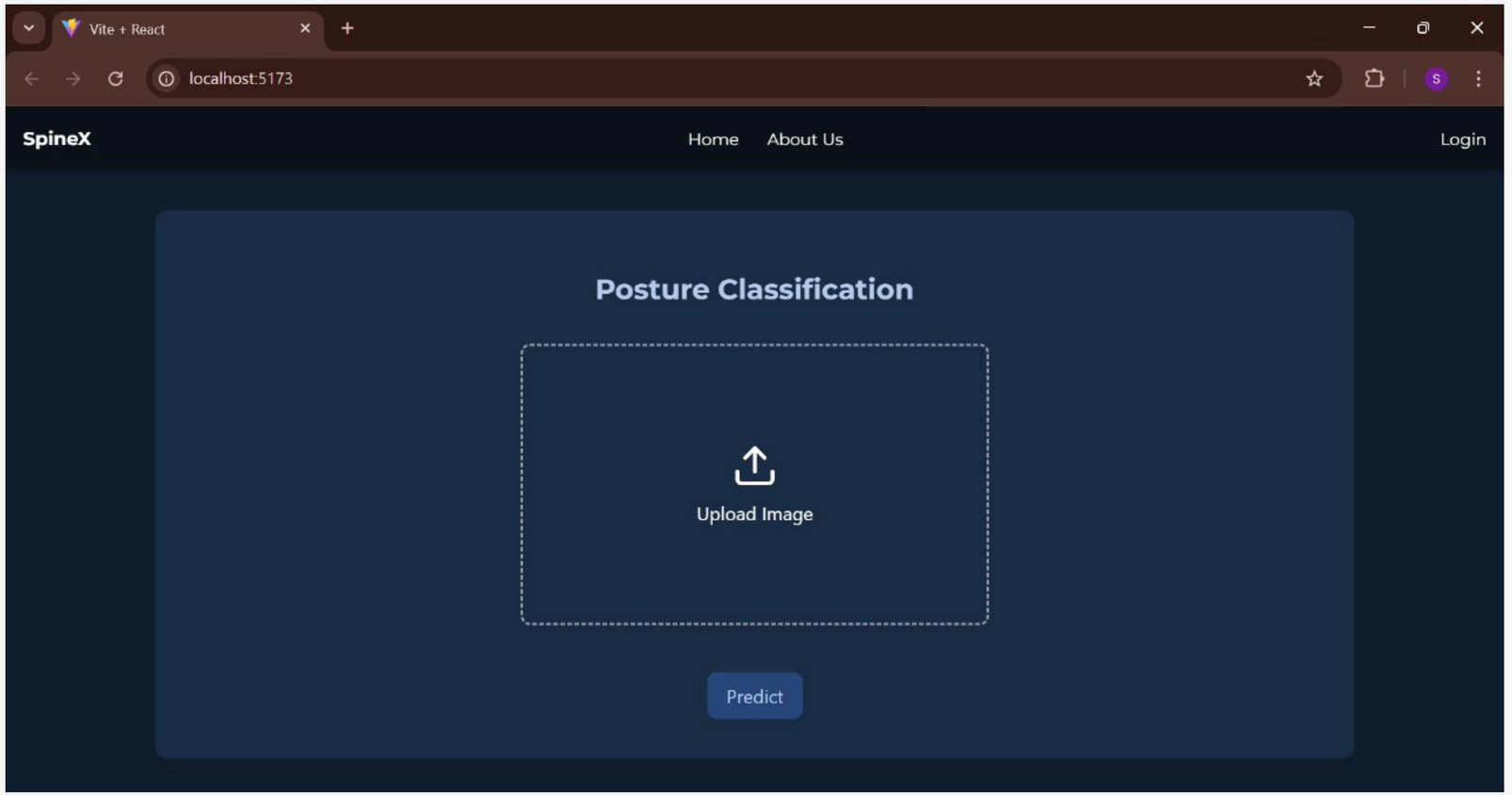
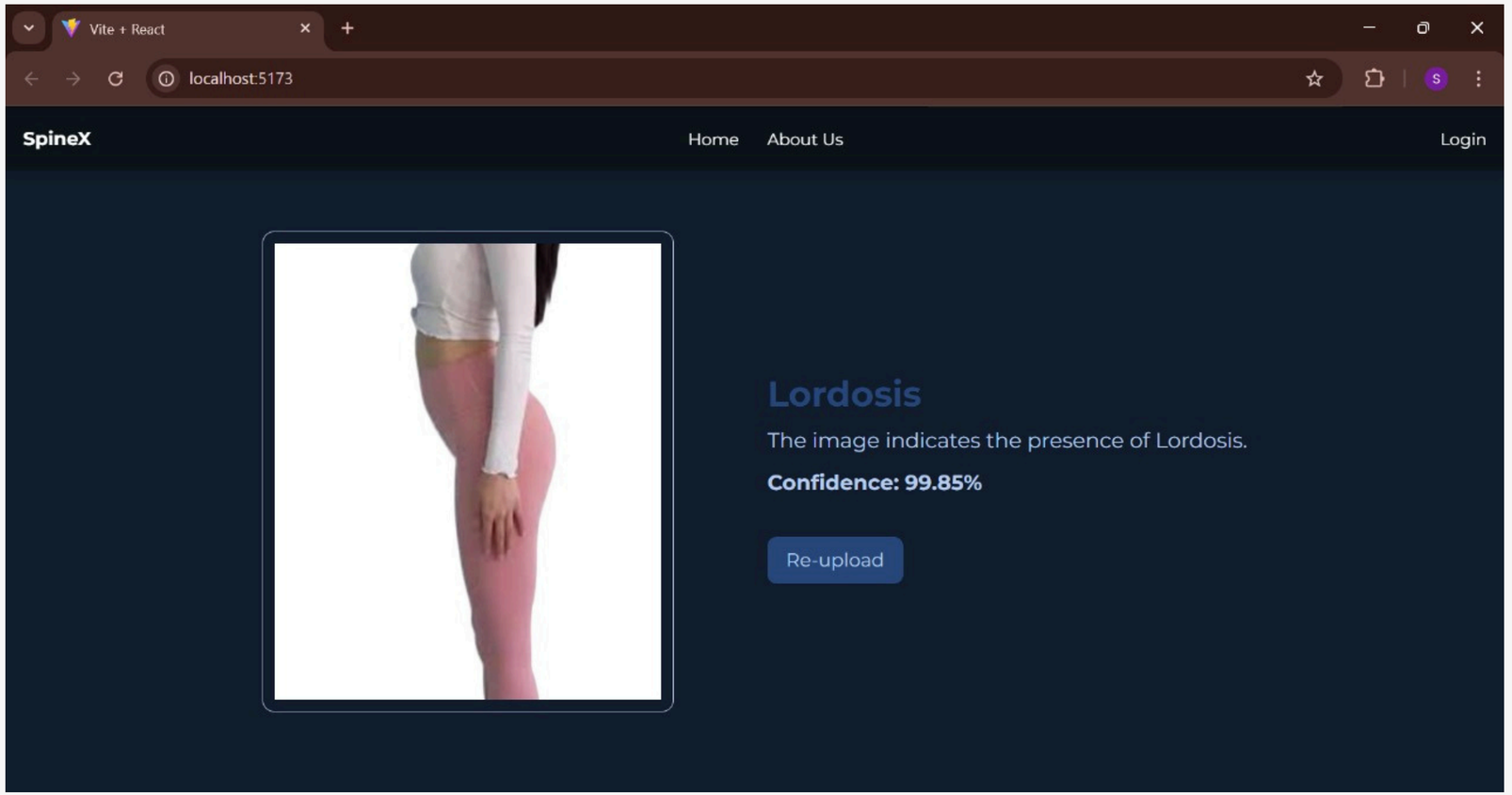
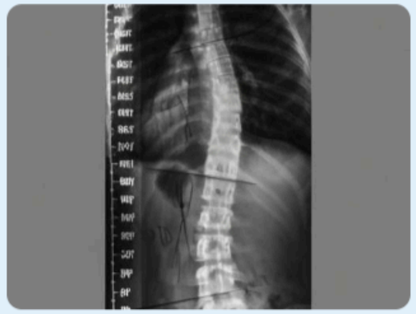
Treatment Recommendation
Cobb Angle: 41.36°
Treatment Recommendation - Severe Scoliosis
If scoliosis progresses beyond 40°, surgical correction is often required.
Types of Scoliosis Surgeries:
Spinal Fusion Surgery: Vertebrae are fused to prevent movement using rods and screws.
Learn More
Growing Rods Surgery: Used for children still growing, where rods are adjusted periodically.
Learn More


Vite + React
localhost:5173
SpineX
Home
About Us
Login
Posture Classification
Upload Image
Predict


Vite + React
localhost:5173
SpineX
Home
About Us
Login
Lordosis
The image indicates the presence of Lordosis.
Confidence: 99.85%
Re-upload

Profile Page



Cobb Angle: 22.42°

Curve Type: C-Shape

Severity: Moderate

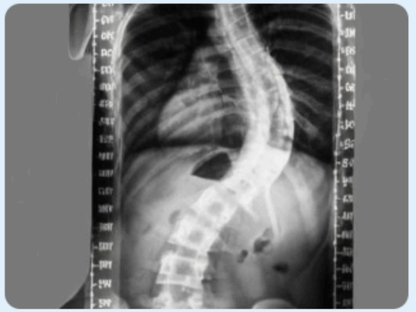
Uploaded: 2024-01-13

Cobb Angle: 36.68°

Curve Type: C-Shape

Severity: Moderate

Uploaded: 2024-08-15

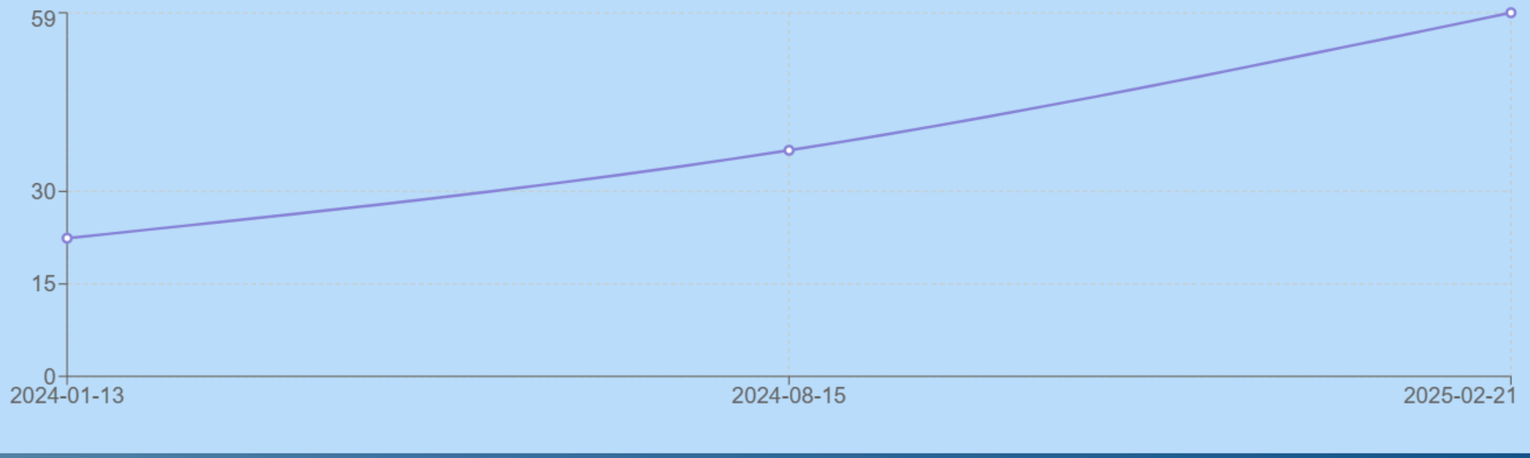


Cobb Angle: 59°

Curve Type: C-Shape

Severity: Severe

Uploaded: 2025-02-21



Recommendation

As the Cobb angle continues to increase, regular monitoring with an orthopedic specialist is essential. Bracing may help slow progression, while scoliosis-specific physical therapy can improve posture. If discomfort arises, pain management strategies like physiotherapy or medication should be considered. Since the angle has exceeded 50 degrees, a surgical evaluation may be necessary. Lifestyle modifications, including good posture and ergonomic support, can also help manage symptoms.

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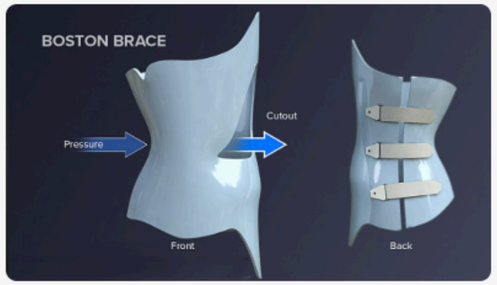
Treatment Recommendation

Cobb Angle: 26.03°

Treatment Recommendation - Moderate Scoliosis

Bracing is recommended to stop further progression of the curve, especially in growing adolescents.

Types of Braces:



Boston Brace: Designed for curves in the mid to lower spine.

Learn More

Milwaukee Brace: Used for high thoracic spine curves, includes a neck ring.

Learn More

FUTURE WORK

- Expand Dataset Diversity for Generalization: Increasing the size and diversity of datasets will improve the model’s ability to generalize across different patient populations, making the system more reliable and effective in real-world clinical settings.

- Real-Time Integration into Clinical Workflows: Implementing the system for real-time use will streamline clinical workflows, providing physicians with immediate insights and AI-assisted treatment recommendations that support faster, more accurate decision-making in diagnosing and managing spinal deformities.

CONCLUSION

- This project aims to improve the diagnosis of spinal deformities, including scoliosis, kyphosis and lordosis through advanced deep learning models.

- By automating the detection and classification of these conditions, it supports healthcare professionals in providing quicker and more accurate assessments. This solution enhances patient care by reducing diagnostic time and offering consistent, reliable analysis.

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THANK YOU