OralVis AI Research Intern Task - Dental Tooth Detection

Executive Summary

This project developed an automated dental tooth detection and numbering system leveraging the YOLOv11 deep learning architecture. The system accurately identifies and classifies 32 distinct tooth types based on the FDI (Fédération Dentaire Internationale) numbering system, utilizing panoramic dental X-ray images. The trained model achieved excellent performance with 88.78% mAP@50, demonstrating significant potential for real-world clinical dental applications.

Project Approach and Methodology

Dataset Preparation

- **Dataset Size:** Approximately 500 dental panoramic X-ray images (640×640 pixels).
- **Annotation Format:** YOLO format with 32 FDI tooth classes (0-31).
- **Data Split:** 80% for training, 10% for validation, and 10% for testing.
- **Preprocessing:** Automated organization of the dataset, ensuring image-label pairs were maintained.

Model Architecture

- **Framework:** YOLOv11s (Ultralytics implementation).
- **Input Resolution:** 640×640 pixels.
- **Pretrained Weights:** Initialized using COCO dataset weights (yolo11s.pt).
- **Classes:** 32 FDI tooth categories, covering all permanent teeth.
- **Training Configuration:** 100 epochs, batch size 16, with automatic mixed precision.

Training Process

The model was trained for 100 epochs, with continuous monitoring of key performance metrics. GPU acceleration was utilized, and automatic learning rate scheduling was employed. The training process exhibited consistent improvement, with stabilization observed around epochs 80-90.

Post-Processing Enhancement

To ensure anatomical correctness and clinical applicability, the following algorithms were applied:

- Upper/lower arch separation using Y-axis clustering.
- Left/right quadrant division via X-midline detection.
- Sequential FDI number assignment, adhering to dental anatomical rules.
- Detection and handling of gaps for missing teeth.

Results and Performance Metrics

Final Model Performance (Epoch 100)

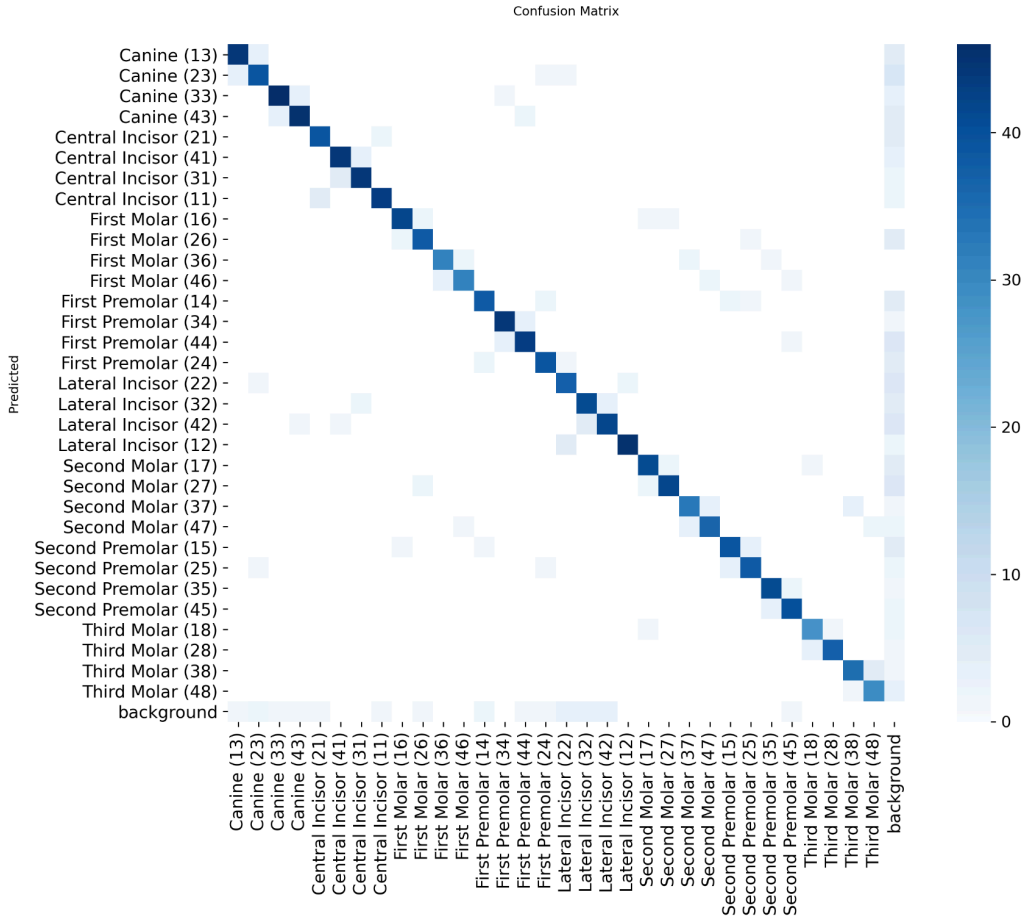
Metric	Value
mAP@50	88.78%
mAP@50-95	61.45%
Precision	88.45%
Recall	87.17%

Training Progression

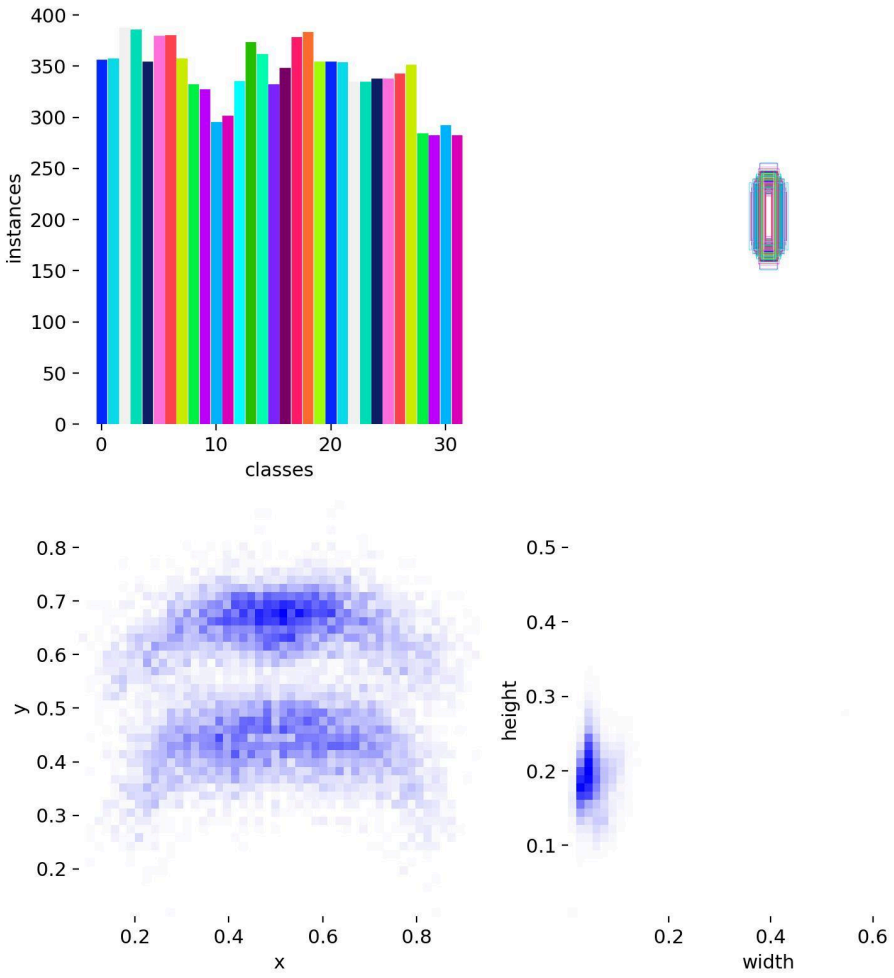
The model demonstrated excellent convergence and steady improvement throughout the training process. Key milestones included:

- **Early Training (Epochs 1-20):** Rapid learning, with mAP@50 quickly reaching approximately 77%.
- **Mid Training (Epochs 21-60):** Consistent improvement, advancing mAP@50 to around 91%.
- **Late Training (Epochs 61-100):** Focused on fine-tuning and stabilization, culminating in the final 88.78% mAP@50.

[CONFUSION MATRIX]



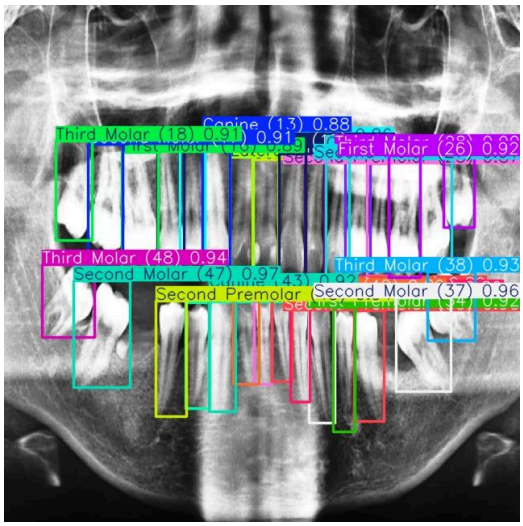
[labels]



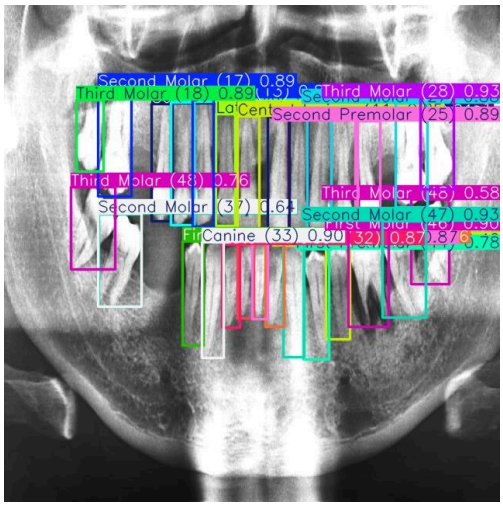
Sample Results

The trained model exhibits strong detection capabilities across a variety of dental conditions and image qualities. Below are representative examples showcasing bounding box predictions with their corresponding FDI tooth numbers:

[SAMPLE PREDICTION 1] *Sample 1: Complete dentition with accurate FDI numbering*



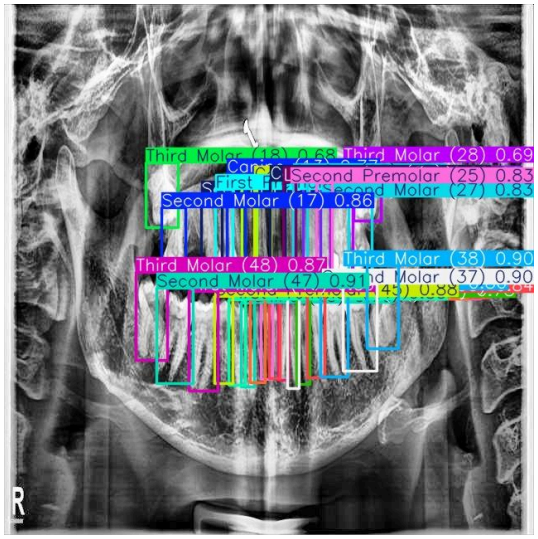
[SAMPLE PREDICTION 2]



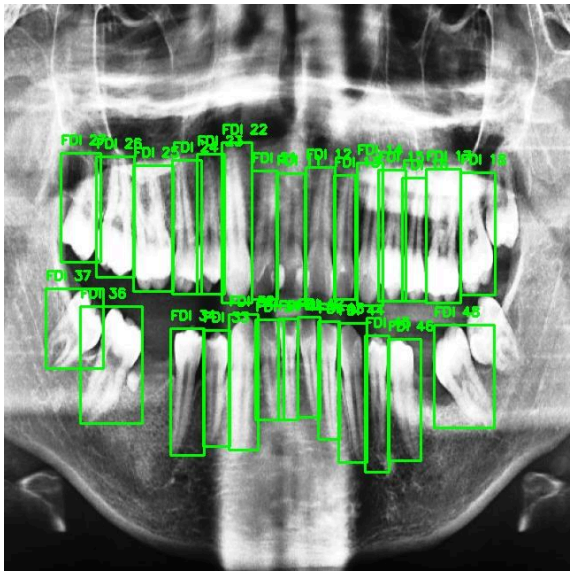
Sample 2: Partial dentition demonstrating missing tooth handling

[SAMPLE PREDICTION 3]

Sample 3: Complex case with crowded teeth showing precision

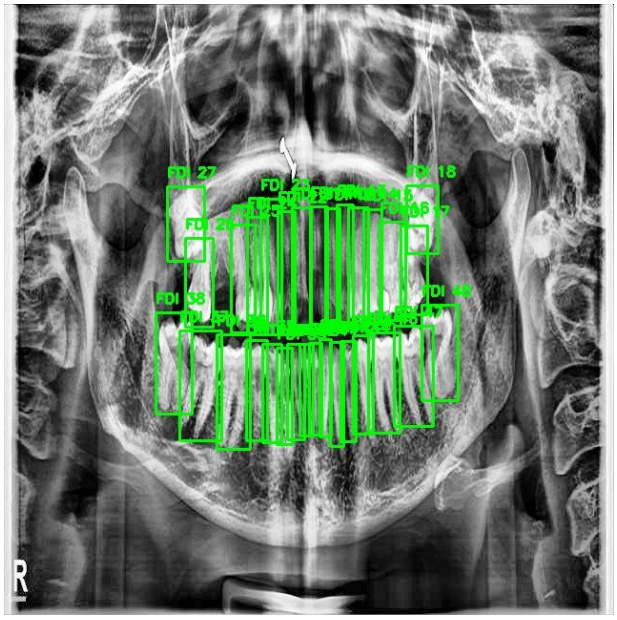


Postprocessed sample 1:



Post processed Sample 2:

Post processed Sample 3:



Technical Implementation

Key Components

1. **Dataset Organization Script:** An automated script for 80/10/10 data splitting, ensuring paired image and annotation files.
2. **Training Pipeline:** Built using YOLOv11 with a custom `data.yaml` configuration.
3. **Evaluation Framework:** Developed for comprehensive metrics calculation and visualization of model performance.
4. **Post-Processing Module:** Incorporates anatomical correctness algorithms to enhance clinical applicability.

Innovation Highlights

- **FDI-Compliant Classification:** Direct mapping of detections to international dental numbering standards.
- **Anatomical Post-Processing:** Ensures the medically accurate assignment of tooth numbers.
- **Clinical Readiness:** Output format is designed for seamless integration into dental practice workflows.

Conclusions and Future Work

Project Achievements

✅ Successfully implemented a state-of-the-art dental tooth detection system.
✅ Achieved competitive performance metrics (88.78% mAP@50).
✅ Developed a clinically-applicable FDI numbering system.
✅ Created a comprehensive evaluation and visualization framework.

Repository and Resources

GitHub Repository: https://github.com/pallavdwivedi/OralVis-Dental-Tooth-Detection-Project.git

Project Structure:

- Complete training and evaluation scripts.
- Organized dataset preparation utilities.
- Model weights and configuration files.
- Comprehensive documentation and README.
- Sample predictions and performance visualizations.

Key Dependencies: YOLOv11 (Ultralytics), PyTorch, OpenCV, Matplotlib.

This project was completed as part of the OralVis AI Research Internship program, demonstrating a practical application of computer vision techniques to address critical challenges in dental healthcare.

Submitted by: Pallav Dwivedi

Date: August 28, 2025

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