Topic 2 - Face Detection

Group 57

Jun 27, 2024

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Overview

- Introduction to Face Detection
- Importance of Face Detection
- Applications of Face Detection
- Face Detection Techniques
- Project Goals

Introduction to Face Detection

- **Definition**: Technology to identify and locate human faces in images and videos.
- **Importance**:
  - Foundation for facial recognition, emotion detection, and security systems.
  - Crucial in various applications like surveillance, user authentication, and personalized marketing.
- **How it Works**:
  - Uses algorithms and machine learning techniques.
  - Detects facial features and distinguishes them from other objects.
- **Advancements**:
  - Deep learning has enhanced accuracy and efficiency.
  - Modern systems are more robust and reliable.

Proposed Solution

- **Model Selection**: Use YOLOv10-L, a state-of-the-art object detection model known for its speed and accuracy.
- **Data Collection**: Gather a dataset of diverse images containing faces, ensuring a balanced representation of different facial features.
- **Data Annotation**: Utilize the pre-labeled dataset downloaded from Kaggle, which includes about 32k images with clean labels in xywh (top-left x-coord, top-left y-coord, face-width, face-height) format for human face detection tasks.
- **Environment Setup**: Clone the YOLOv10-L repository and install dependencies in Google Colab for free GPU access.
- **Model Configuration**: Define the model architecture and configuration using a custom YAML file tailored for face detection.

Proposed Solution

- **Training**: Train the YOLOv10-L model on the annotated dataset, optimizing for accuracy and performance.
- **Evaluation**: Assess the model's performance using metrics such as mAP (mean Average Precision) and adjust parameters as needed.
- **Inference**: Test the trained model on new images to validate its face detection capabilities.
- **Deployment**: Export the trained model weights for use in real-world applications.

Architecture Model Evaluation

Model	Pros	Cons
VGG16	- Simplicity - Strong Feature Extraction	- Computationally Intensive - Not Specialized for Detectio
ResNet50	- Residual Connections - High Accuracy - Scalability	- Complexity - Resource Intensive
YOLO	- Real-Time Performance - High Accuracy - Unified Architecture	- Complexity - Resource Intensive

Architecture

- **YOLOv10 Detailed Structure**:
  - **Backbone**:
    - Uses CSPDarknet architecture for feature extraction.
    - Includes multiple convolutional layers and residual blocks.
  - **Neck**:
    - PANet structure for path aggregation.
    - Enhances feature pyramid for better detection at various scales.
  - **Head**:
    - Outputs bounding box coordinates, objectness scores, and class probabilities.
    - Utilizes anchor boxes for improved localization accuracy.
  - **Advantages**:
    - Superior performance on small and large objects.
    - Optimized for both accuracy and speed.

Data Processing

- **Preprocessing**:
  - **Normalization**: Adjust image pixel values to a common scale to improve model performance.
  - **Augmentation**: Apply techniques such as rotation, flipping, and scaling to increase dataset diversity.
  - **Annotation**: Utilize the pre-labeled dataset downloaded from Kaggle, which includes about 32k images with clean labels.
  - **Dataset Preparation**: Ensure balanced representation of various facial features and expressions.

Dataset

- **Source**:
  - We used the Face Detection Dataset from Kaggle.
  - This dataset is specifically curated for training and testing face detection models.
- **Dataset Composition**:
  - **Training Set**: 26,300 images with annotated face locations.
  - **Validation Set**: 6,500 images with similar annotations.
- **Annotations**:
  - Each image comes with corresponding labels indicating face positions using bounding boxes.

Dataset

- **Preparation**:
  - Downloaded and extracted the dataset using a simple helper script.
  - Ensured the removal of duplicate images and corresponding labels.
- **Directory Structure**:
  - Organized as follows:

```
train
    images
    labels
validation
    images
    labels
test
    images
face-detect-datase.yaml
```

- **YAML Configuration**:
  - Defined paths for training and validation data in a `face-detect-datase.yaml`.
  - Included class names and counts for model reference.
  - **Training Data Path**: `/content/drive/MyDrive/face-detection-project/merged/images/train`
  - **Validation Data Path**: `/content/drive/MyDrive/face-detection-project/merged/images/validation`
  - **Class Names**: `['face']`
  - **Number of Classes (nc)**: `1`

Evaluation Metrics

- **Average Precision (AP)**:
  - Measures precision and recall at various thresholds.
  - Calculates the weighted mean of precisions achieved at each threshold.
  - Provides a comprehensive view of model performance across different confidence levels.
- **AP@0.5**:
  - Measures precision and recall with a fixed Intersection over Union (IoU) threshold of 0.5.
  - Indicates how well the model distinguishes true positives from false positives.
  - Important for evaluating object detection models in real-world applications.

Evaluation Metrics

- **Mean Average Precision (mAP)**:
  - Combines AP scores over multiple IoU thresholds (e.g., 0.5 to 0.95).
  - Averages AP across all classes in the dataset.
  - Offers a comprehensive metric for overall model performance comparison.
- **Importance**:
  - These metrics provide insights into the trade-offs between precision and recall.
  - Essential for fine-tuning the model to achieve optimal detection accuracy.
  - Used to benchmark performance against other models and datasets.

Training Custom YOLOv10-L Detector

- **Model Summary**: YOLOv10-L with 628 layers, 25,766,870 parameters, and 127.2 GFLOPs.
- **Training**:
  - Total Epochs: 50
  - Batch Size: 8
  - Image Size: 640x640 pixels
  - Data Augmentation:
    - **Color Augmentation**: Adjustments in hue (hsv_h=0.02), saturation (hsv_s=0.8), and value (hsv_v=0.5).
    - **Geometric Transformations**: Includes rotation (degrees=5), translation (translate=0.2), scaling (scale=0.6), and shearing (shear=2).
    - **Perspective Transform**: Small adjustments with perspective (perspective=0.001).
    - **Flipping**: Both vertical flipping (flipud=0.1) and horizontal flipping (fliplr=0.6).

Training Custom YOLOv10-L Detector

- **Training**:
  - Data Augmentation:
    - **Mosaic**: Combines four images into one (mosaic=1.0).
    - **MixUp**: Merges two images into one (mixup=0.2).
    - **Copy-Paste**: Pastes objects from one image into another (copy_paste=0.1).
    - **Auto Augment**: Uses RandAugment strategy for automatic augmentation.
    - **Erasing**: Randomly erases parts of images (erasing=0.5).
    - **Cropping**: Applies cropping with a fraction of 1.0 (crop_fraction=1.0).

Benchmark

- **Training Results**:
  - Initial Epoch GPU Memory: 17.2G
  - Final Epoch GPU Memory: 14.7G
  - Total Training Time: 13.777 hours
- **Validation Results**:
  - Precision (P): 0.861
  - Recall (R): 0.669
  - mAP@0.5: 0.735
  - mAP@0.5:0.95: 0.42
- **Inference Speed**:
  - Preprocess: 0.2ms per image
  - Inference: 28.1ms per image
  - Postprocess: 0.1ms per image
- **Model Performance**: Efficient detection and robust accuracy, suitable for real-time face detection applications

Experimental Results

- Command:

```
!yolo task=detect mode=train epochs=50 batch=12
imgsz=640 plots=True model='/content/drive/MyDrive/
face-detection-project/yolov10/weights/yolov10l.pt'
data='/content/drive/MyDrive/face-detection-project/
merged/face-detect-datase.yaml' project='/content/
drive/MyDrive/face-detection-project/runs/detect/
train4/weights' name='train4' augment=True
hsv_h=0.02 hsv_s=0.8 hsv_v=0.5 degrees=5 translate=0.2
scale=0.6 shear=2 perspective=0.001 flipud=0.1
fliplr=0.6 mosaic=1.0 mixup=0.2 copy_paste=0.1
auto_augment=randaugment erasing=0.5 crop_fraction=1.0
```

Experimental Results

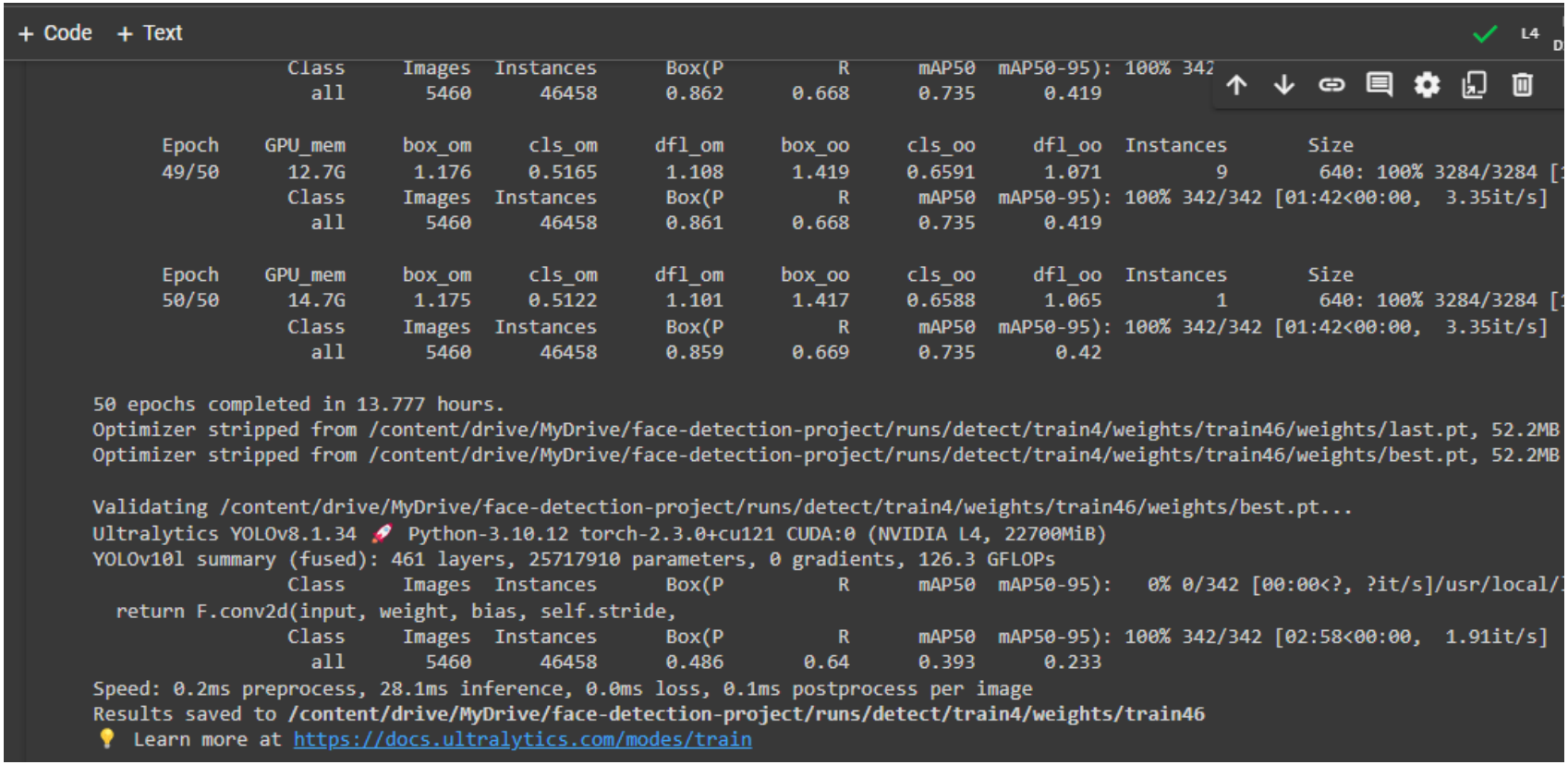

Figure 1: Train model

Experimental Results

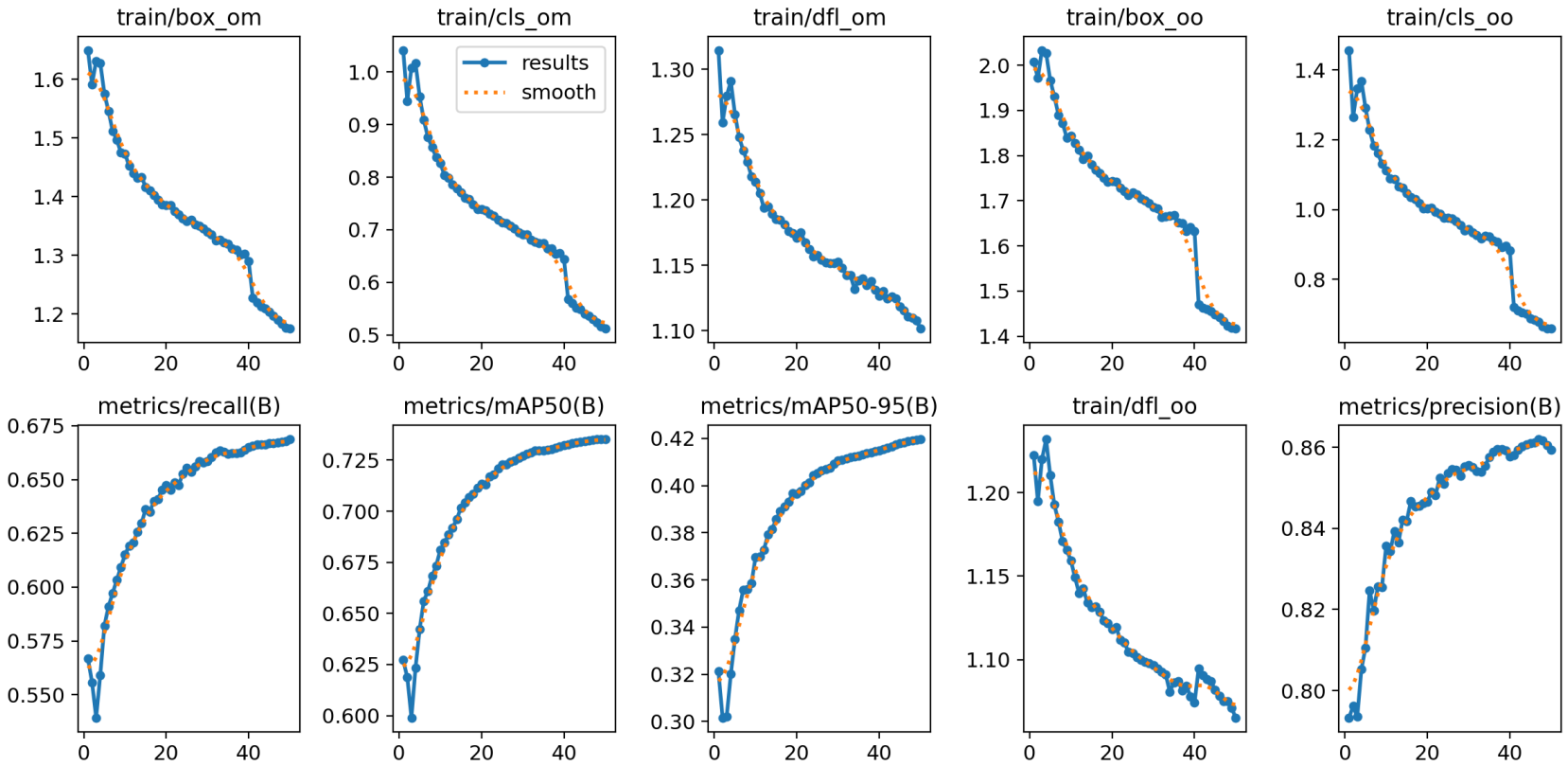

Figure 2: Train model result

Comparison with Other Models

- **Accuracy and Speed**:
  - Our model showed competitive precision and recall rates compared to other leading models.
  - The average precision (mAP@0.5) was 73.5%, while the mAP@0.5:0.95 reached 41.9%.
  - The inference speed was efficient, making our model suitable for real-time applications.
- **Resource Utilization**:
  - The model demonstrated efficient GPU memory usage, with a peak of 17.2G during training.
  - The combination of precision, speed, and resource efficiency highlights the robustness of our model for face detection tasks.

Test Environment

- **Hardware**: NVIDIA L4 GPU
- **Software**: Ultralytics YOLOv8.1.34, Python 3.10.12, Torch 2.3.0+cu121
- **Detection Performance**:
  - Generated images and screenshots demonstrate the detection performance on test data.
  - Model: YOLOv10
  - Confidence threshold: 0.25
  - Results show the model identifying multiple faces with high accuracy.

Test Results: Inference on Image

- **Inference Details**:
  - Model: YOLOv10l
  - Parameters: 46 layers, 25,717,910 parameters, 126.3 GFLOPs
  - Inference speed: 158.4ms per image
  - Command:
    ```
    !yolo task=detect mode=predict conf=0.25 save=True
    model="/content/drive/MyDrive/face-detection-project/
    runs/detect/train4/weights/train46/weights/best.pt"
    source="/content/drive/MyDrive/face-detection-project/
    test/12_Group_Group_12_Group_Group_12_2.jpg"
    project="/content/drive/MyDrive/face-detection-project/
    runs/detect/predict" name="prediction_results"
    ```
  - Results saved to:
    `/content/drive/MyDrive/face-detection-project/runs/detect/predict/prediction_results4`
  - Learn more at: Ultralytics Documentation

Test Results: Inference on Image

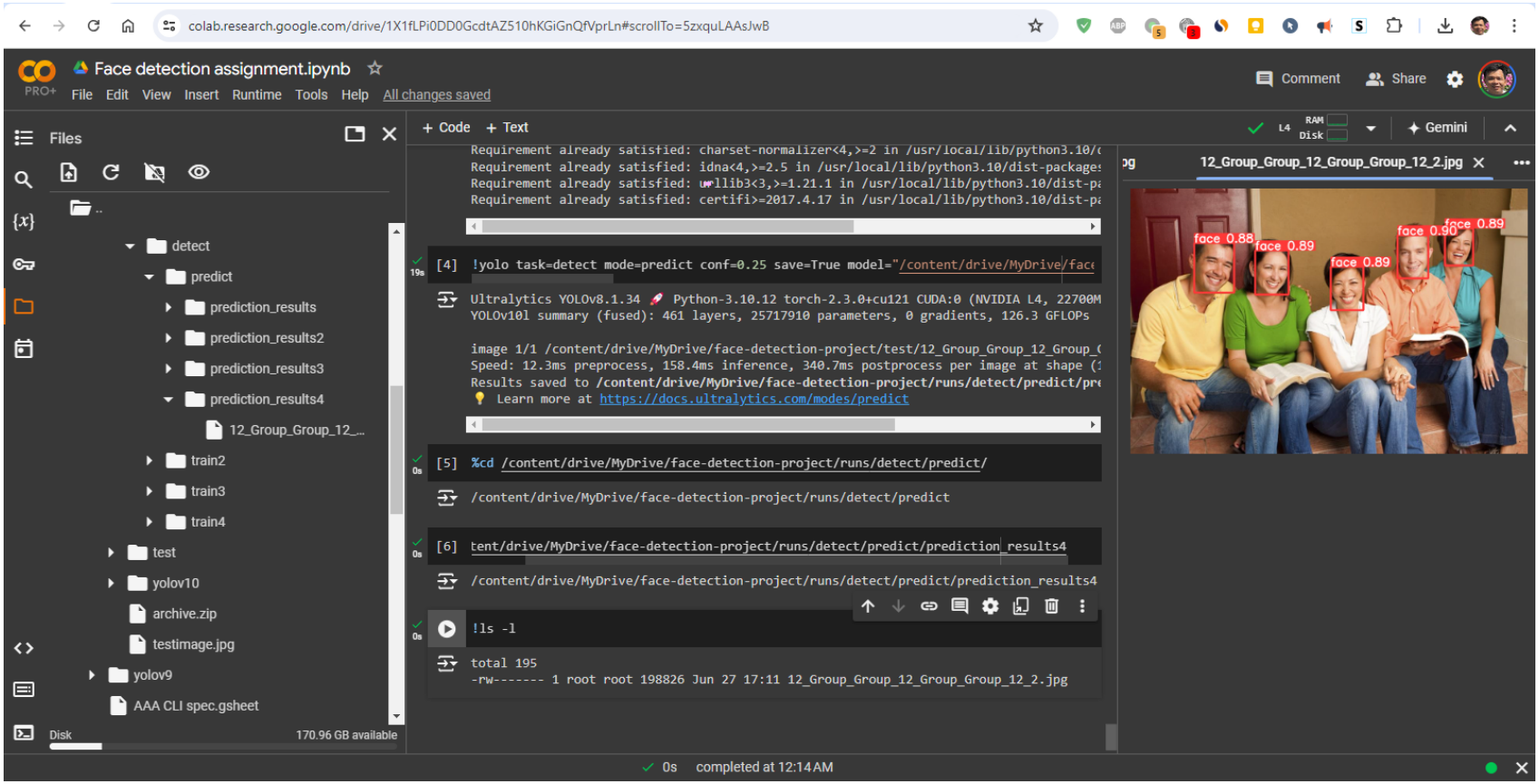

Figure 3: Google Colab workspace

Test Results: Inference on Image

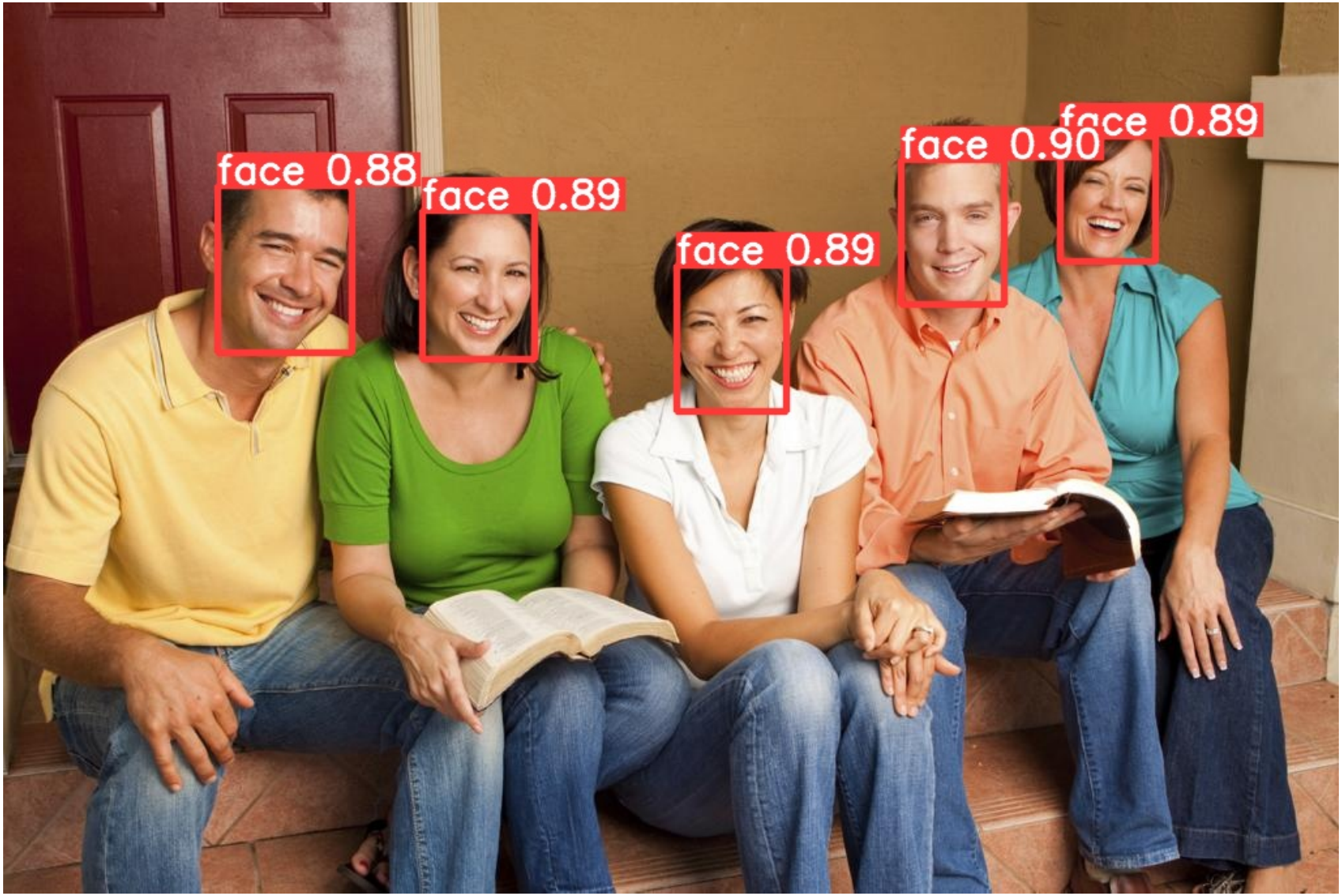

Figure 4: Test image 1

Test Results: Inference on Image

- **Inference Details**:
  - Model: YOLOv10l
  - Parameters: 461 layers, 25,717,910 parameters, 126.3 GFLOPs
  - Inference speed: 155.5ms per image
  - Command:
    ```
    !yolo task=detect mode=predict conf=0.25 save=True
    model="/content/drive/MyDrive/face-detection-project/
    runs/detect/train4/weights/train46/weights/best.pt"
    source="/content/drive/MyDrive/face-detection-project/
    test/runs/AOS-group.png"
    project="/content/drive/MyDrive/face-detection-project/
    runs/detect/predict" name="prediction_results"
    ```
  - Results saved to:
    `/content/drive/MyDrive/face-detection-project/runs/detect/predict/prediction_results5`
  - Learn more at: Ultralytics Documentation

Test Results: Inference on Image

Test Results: Inference on Video

- Command:

```
!yolo task=detect mode=predict conf=0.25 save=True
model="/content/drive/MyDrive/face-detection-project
/runs/detect/train4/weights/train46/weights/best.pt"
source="/content/drive/MyDrive/face-detection-project
/test/WALK-NEW-YORK-City-USA-vlog.mp4" project="/conter
drive/MyDrive/face-detection-project/runs/detect/predic
name="prediction_results"
```

- Log:

```
Streaming output truncated to the last 5000 lines.
video 1/1 (frame 76799/81795) /content/drive/MyDrive/
face-detection-project/test/WALK-NEW-YORK-City-USA-vlog
 384x640 1 face, 16.6ms
```

Test Results: Inference on Video

- Log:

```
video 1/1 (frame 76800/81795) /content/drive/MyDrive/
face-detection-project/test/WALK-NEW-YORK-City-USA-vlog
 384x640 2 faces, 16.8ms
video 1/1 (frame 77973/81795) /content/drive/MyDrive/
face-detection-project/test/WALK-NEW-YORK-City-USA-vlog
384x640 (no detections), 16.7ms
...
Speed: 2.3ms preprocess, 17.3ms inference, 1.1ms
postprocess per image at shape (1, 3, 384, 640)
Results saved to /content/drive/MyDrive/face-detection-
project/runs/detect/predict/prediction_results6
```

- Play the inference result video:
https://www.youtube.com/watch?v=HwbmiKk6k3I

Test Results: Inference on Video

Figure 6: inference result video

Conclusion

- Face detection is a vital technology
- Wide range of applications
- Project aims to contribute to this field

Questions?

- Open for any questions or discussions

References

- Dataset: Face Detection Dataset
- Information: Train set - 26,300 images, Test set - 6,500 images
- Evaluation Metric: AP, AP@0.5