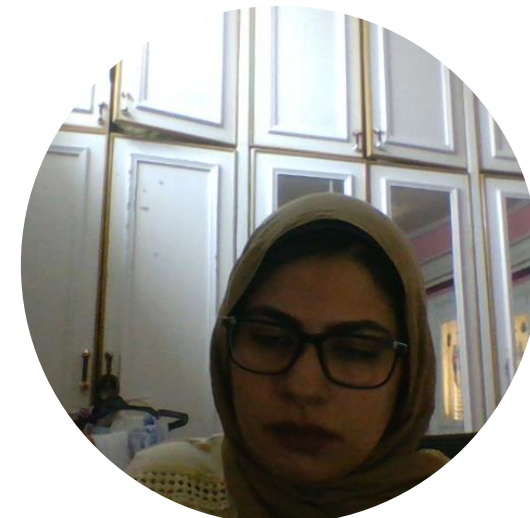
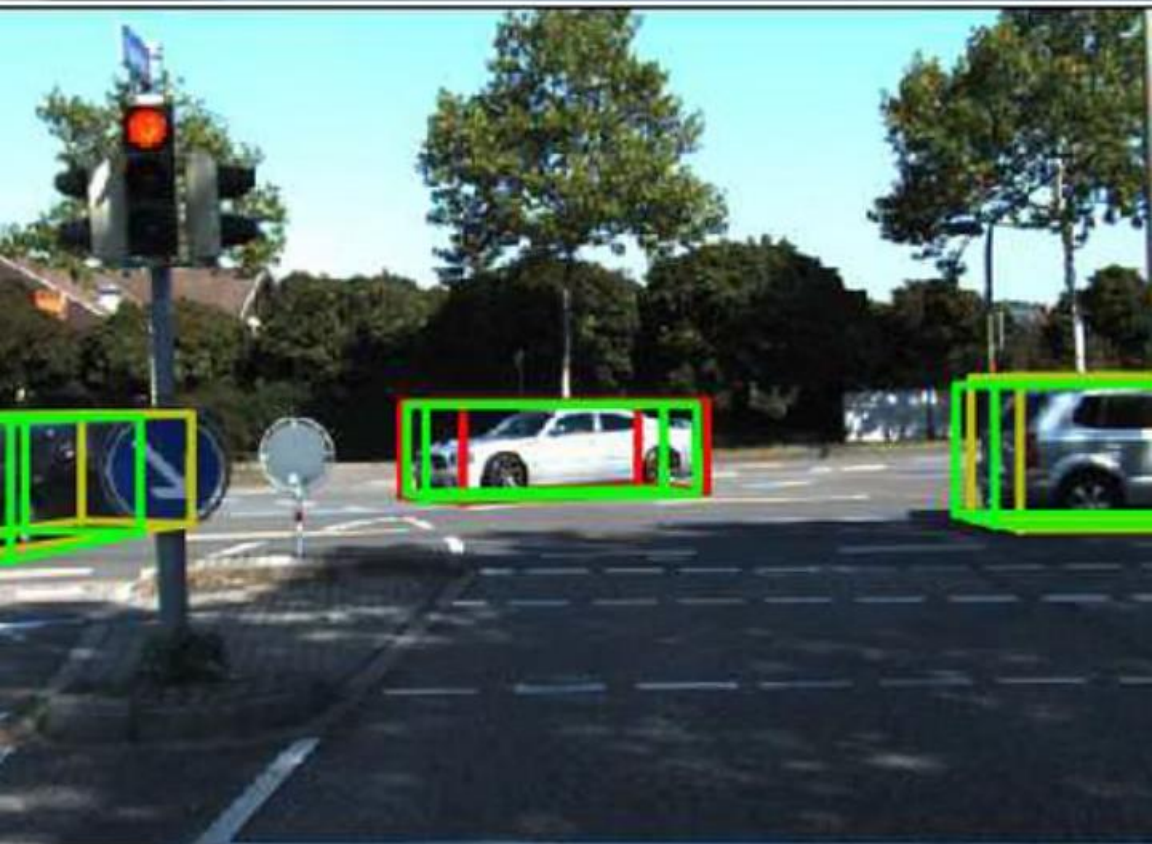


Automated Vehicle-Level Feature Annotation Tool

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Major: Computer Science and Engineering

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Project Outline

1. Introduction
2. My Problem Formulation
3. Literature Review
4. Research Gap
5. Thesis Objective
6. Methodology Design & Implementation
 1. Explore **2D automatic annotation** using YOLOv3, YOLOv11 (combined with Depth Anything v2) and **3D manual annotation** using OpenCV, CVAT, and Mindkosh.
 2. Demos
7. Results and Discussion : Present samples from YOLOv3, CVAT/Mindkosh, and annotated video frames and outputs of the models .
8. Conclusion
9. Future Recommendations
10. Questions



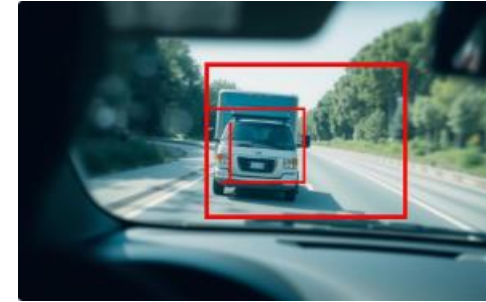
Introduction



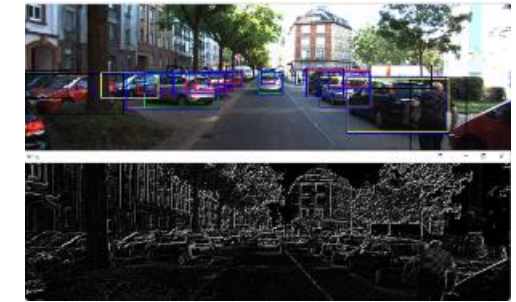
In the field of Autonomous driving and intelligent transportation systems ,high-quality annotated datasets are crucial for training and evaluating perception models



These datasets typically include detailed information about vehicles—such as position, speed, orientation, and dimensions—extracted from sensor data or visual input.



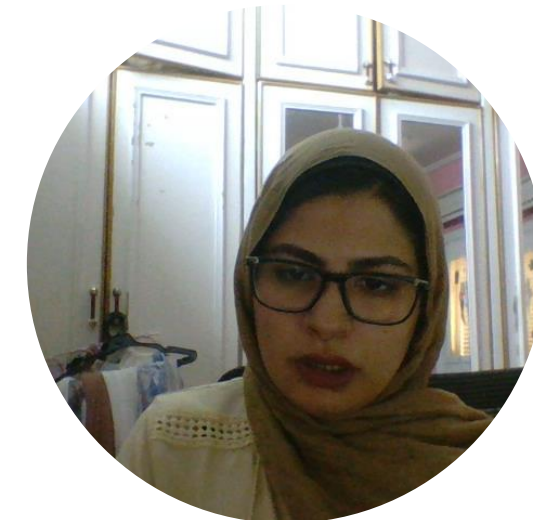
While 2D annotations are widely used, they offer limited spatial understanding.



This project focuses on developing a tool for automated vehicle-level feature annotation

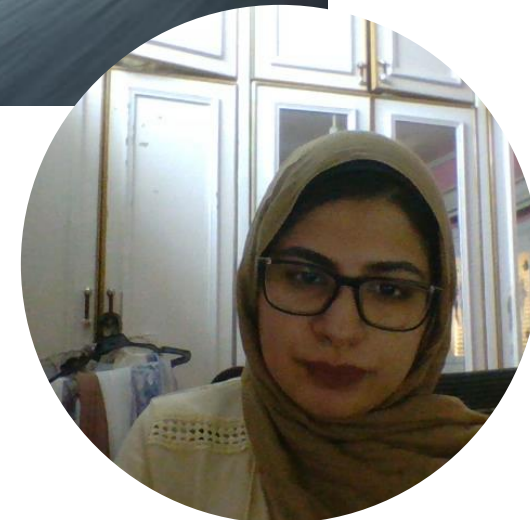


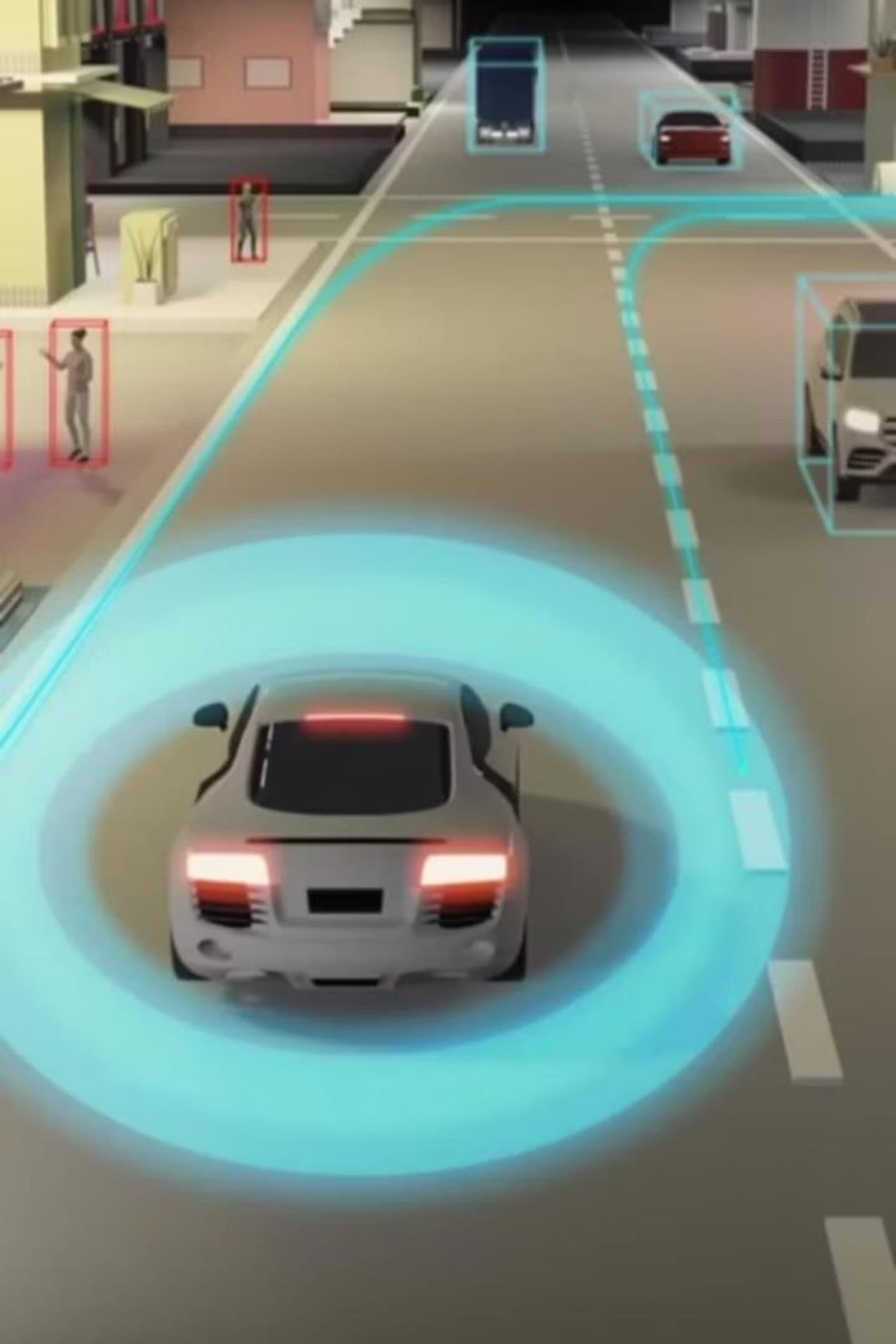
Using monocular camera data, with the goal of enhancing scene understanding in a low-cost, sensor-free environment.



problem formulation

- Current vehicle-level annotation tools often rely on 2D bounding boxes or sensor fusion (e.g., LiDAR, radar) to capture features like speed, orientation, and dimensions.
- However, these approaches either lack spatial depth or require expensive hardware.
- Moreover, manual annotation—especially for 3D bounding boxes—is time-consuming and error-prone, leading to inconsistencies in training data.
- This project addresses the dual challenge of (1) achieving accurate, sensor-free vehicle feature extraction using only monocular camera input and 3D bounding box annotations, and (2) improving the efficiency and consistency of the annotation process for rich feature labeling (e.g., velocity, orientation, inter-vehicle distance, time-to-collision).





Literature Review Summary

Most Commonly Detected Vehicle Features

- Vehicle Type
- Trajectory & Speed
- 3D Bounding Box (Position, Orientation, Dimensions)
- License Plate / ID
- Object Motion Status (Moving / Stationary)

Popular Detection Methods

- YOLO / CNN-based Object Detection
- LiDAR Point Cloud Segmentation
- Sensor Fusion (Camera + LiDAR + Radar)
- 3D Object Detection (PointNet, VoxelNet)
- Manual Annotation / Labelling



Extended Literature Review: Monocular 3D Object Detection

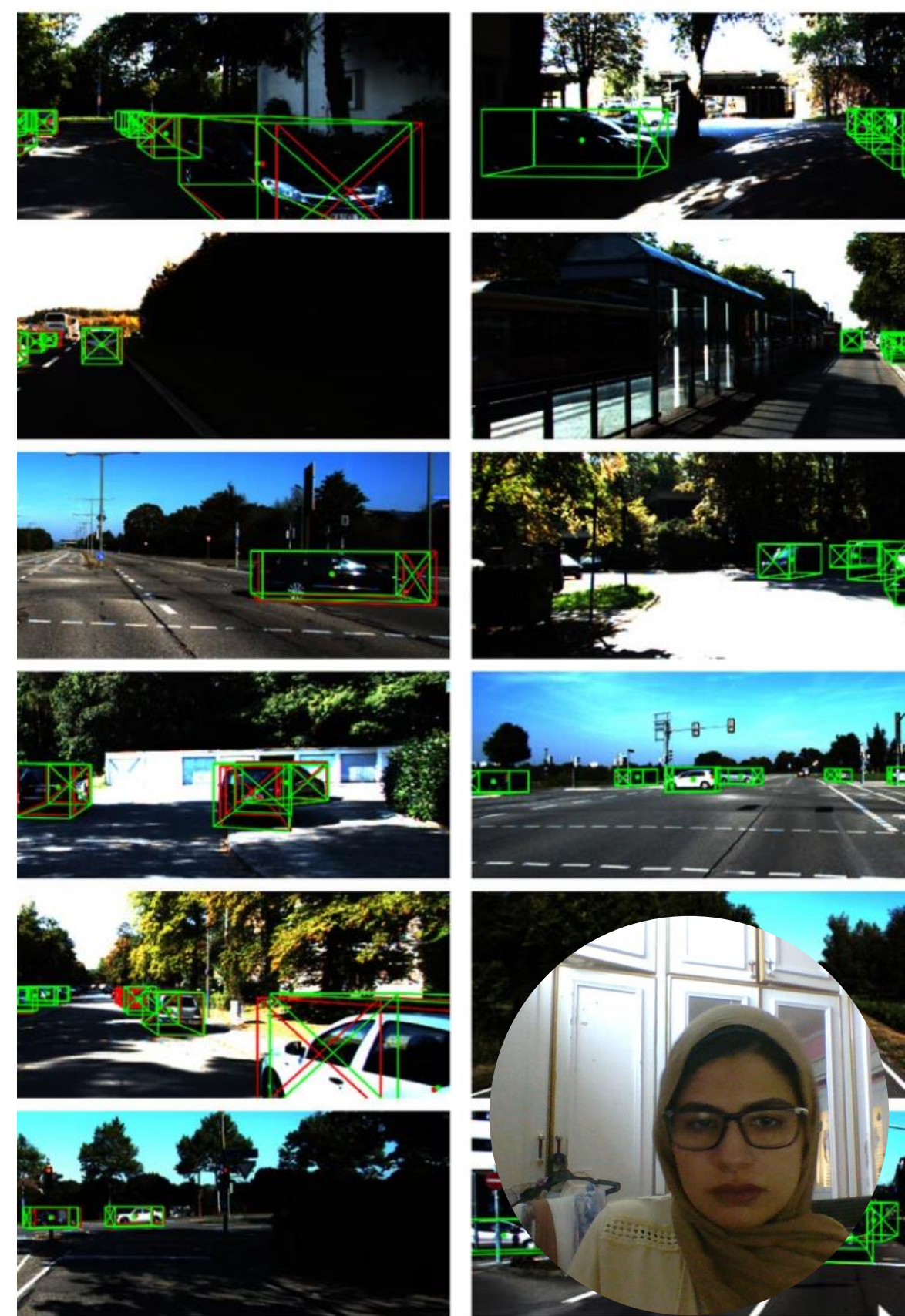
In the last two weeks, I expanded my literature review by exploring recent monocular 3D object detection models using Papers with Code and Google Scholar. I studied papers indexed from 21 to 27 in my spreadsheet:, which provided a variety of models suitable for automatic annotation tasks.

Key insights from these papers:

- Rapid advancements in monocular 3D detection without the need for expensive LiDAR sensors.
- Diverse model architectures focusing on depth estimation, 3D localization, and bounding box refinement.
- Available models offer different trade-offs between accuracy, speed, and computational efficiency.
- Several models showed strong potential for vehicle feature extraction directly from monocular images, enabling efficient dataset annotation.

This exploration helped me select potential candidates for automatic annotation, including YOLOv8+Depth, YOLOv11+Depth Anything v2, and MonoLSS.

Spreadsheetlink:https://1drv.ms/x/c/5962268546b6d7e5/ETV2CZ7LUBNnt_BeV_03efQB4MIPjgUBIb6lZJhG02Iyxg?e=gk3DVA&nav=MTVfezNERFEODZDLTKwRUUtNDU3RC05MUYYLTZCOEY5QzQwMkMyMH0



Research Gap



Most existing datasets and annotation tools either rely heavily on LiDAR/radar or offer only 2D bounding box annotations.



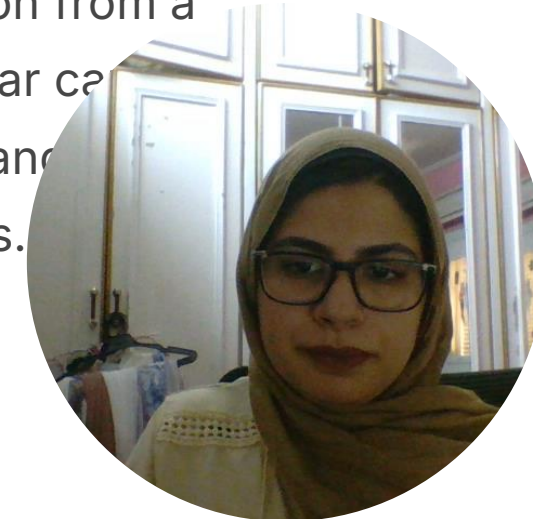
Monocular 3D detection models are improving, but their integration into annotation tools for vehicle-level feature extraction is still limited.



Limited work is available on extracting detailed dynamic features (velocity, acceleration, inter-vehicle distance) from monocular 3D outputs without sensor fusion.



Lack of accessible and standardized pipelines for fully automatic 3D annotation from a monocular camera for training and testing purposes.



My topic Objectives



Develop a 3D annotation tool for vehicles using only monocular camera data.



Extract detailed vehicle-level features such as velocity, acceleration, dimensions, and orientation.



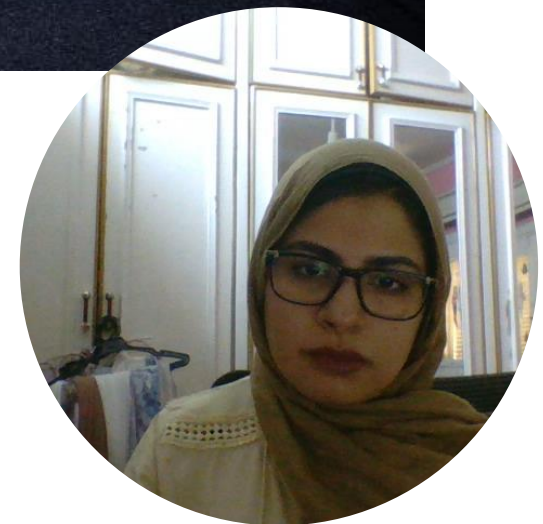
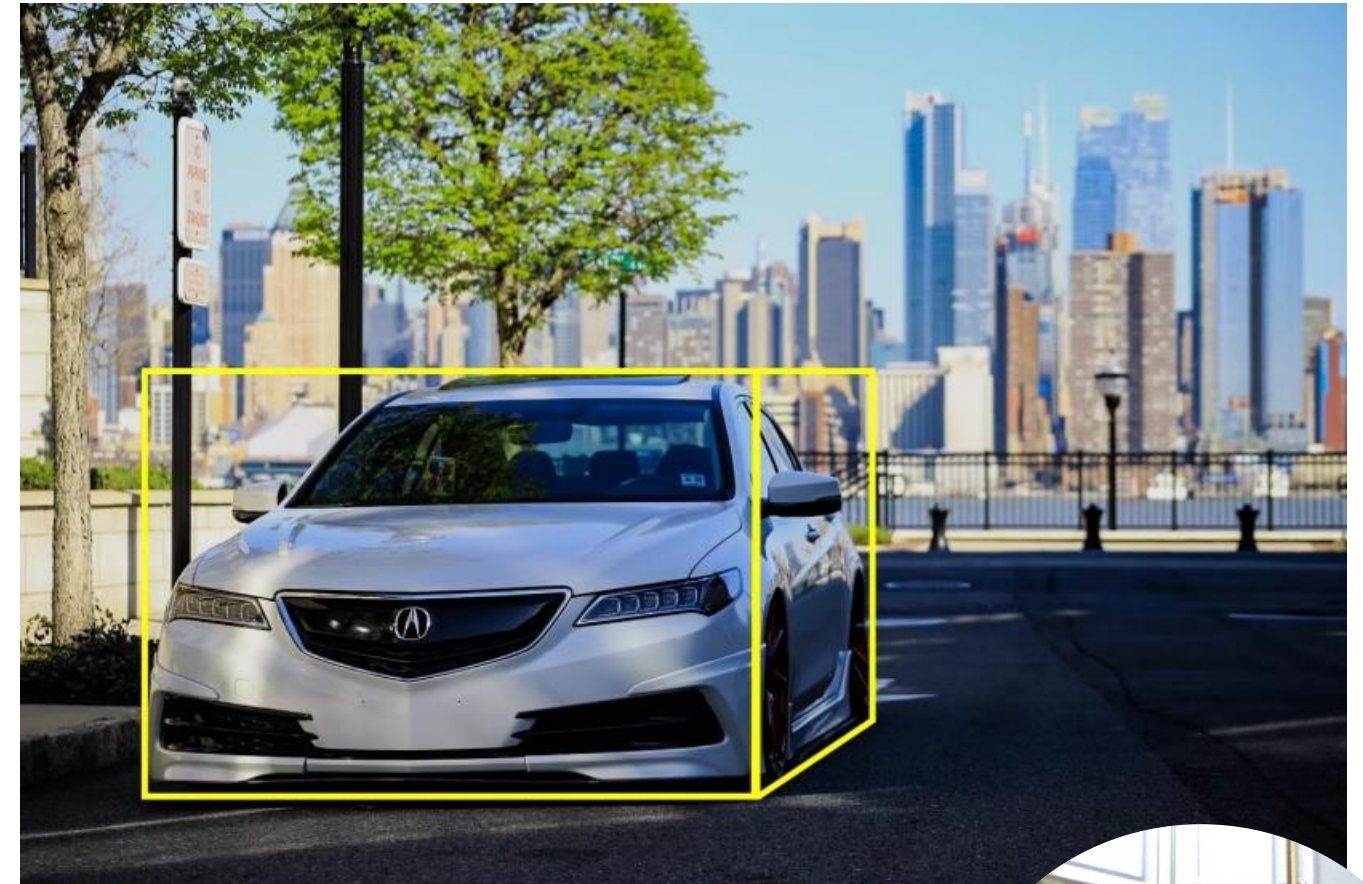
Compare different monocular 3D detection models for annotation efficiency and accuracy.



Reduce reliance on expensive sensors while maintaining rich scene understanding.



Propose a pipeline for efficient vehicle feature annotation and validate it on real-world datasets.



Methodology & Implementation

1. Early Stage:

- Automated 2D vehicle detection using YOLOv3.
- Manual 3D annotation using OpenCV, CVAT, and Mindkosh platforms.

2. Mid Stage:

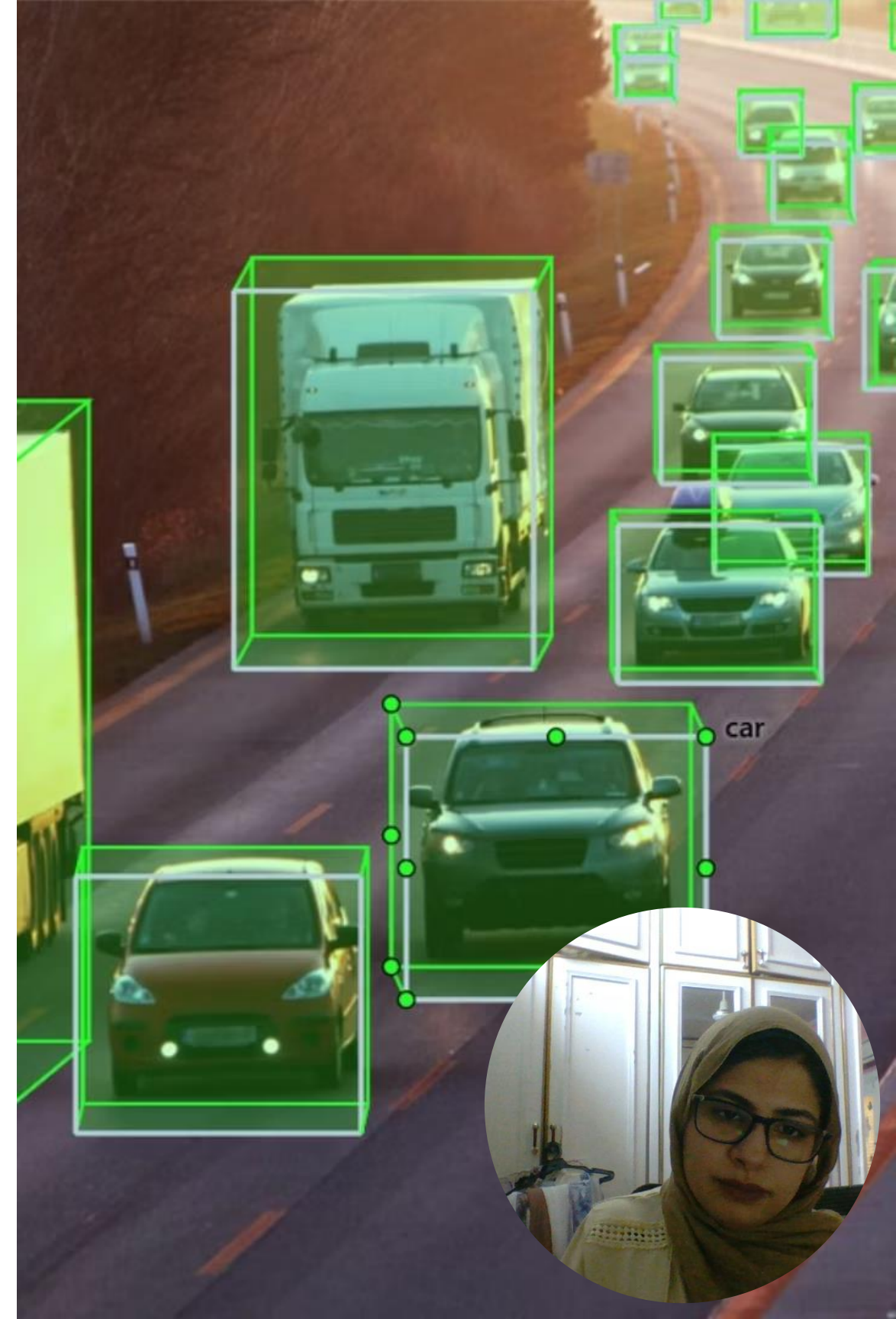
- Semi-automated annotation using YOLOv11 with Depth Anything v2.
- Extracted vehicle-level features: 3D bounding box dimensions, centroids, velocities, accelerations, inter-vehicle distances.

3. Current Stage:

- Training and evaluating MonoLSS on KITTI dataset.
- Comparing performance with YOLOv11 + Depth Anything v2 outputs.
- Feature extraction improvements: occlusion handling, time-to-collision estimation.

4. Challenges:

- Code unavailability for some models (e.g., YOLOBU).
- Selection of best monocular 3D model based on practical considerations.



Why You Chose MonoLSS over Others

Why MonoLSS?

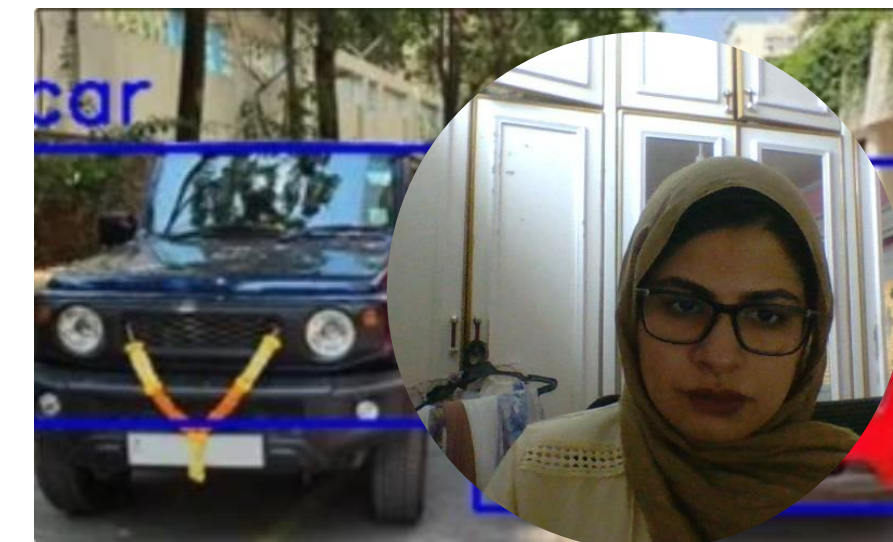
- **Compared to MoGDE:**
- MonoLSS better models geometric depth explicitly rather than only depth prediction.
- **Compared to MonoCAN:**
- MonoCAN uses uncertainty-aware attention but underperforms in spatial accuracy compared to MonoLSS.
- **Compared to Implicit3DUnderstanding:**
- MonoLSS directly supervises depth and geometry, making it easier to train and generalize without complex implicit learning techniques.
- **Compared to SMOKE:**
- SMOKE predicts 3D boxes from 2D heatmaps but struggles with depth ambiguity. MonoLSS addresses depth supervision better, leading to more reliable 3D positions.
- **Overall:**
- MonoLSS strikes a strong balance between detection performance, training stability, and implementation simplicity—making it ideal for an annotation tool.



Results

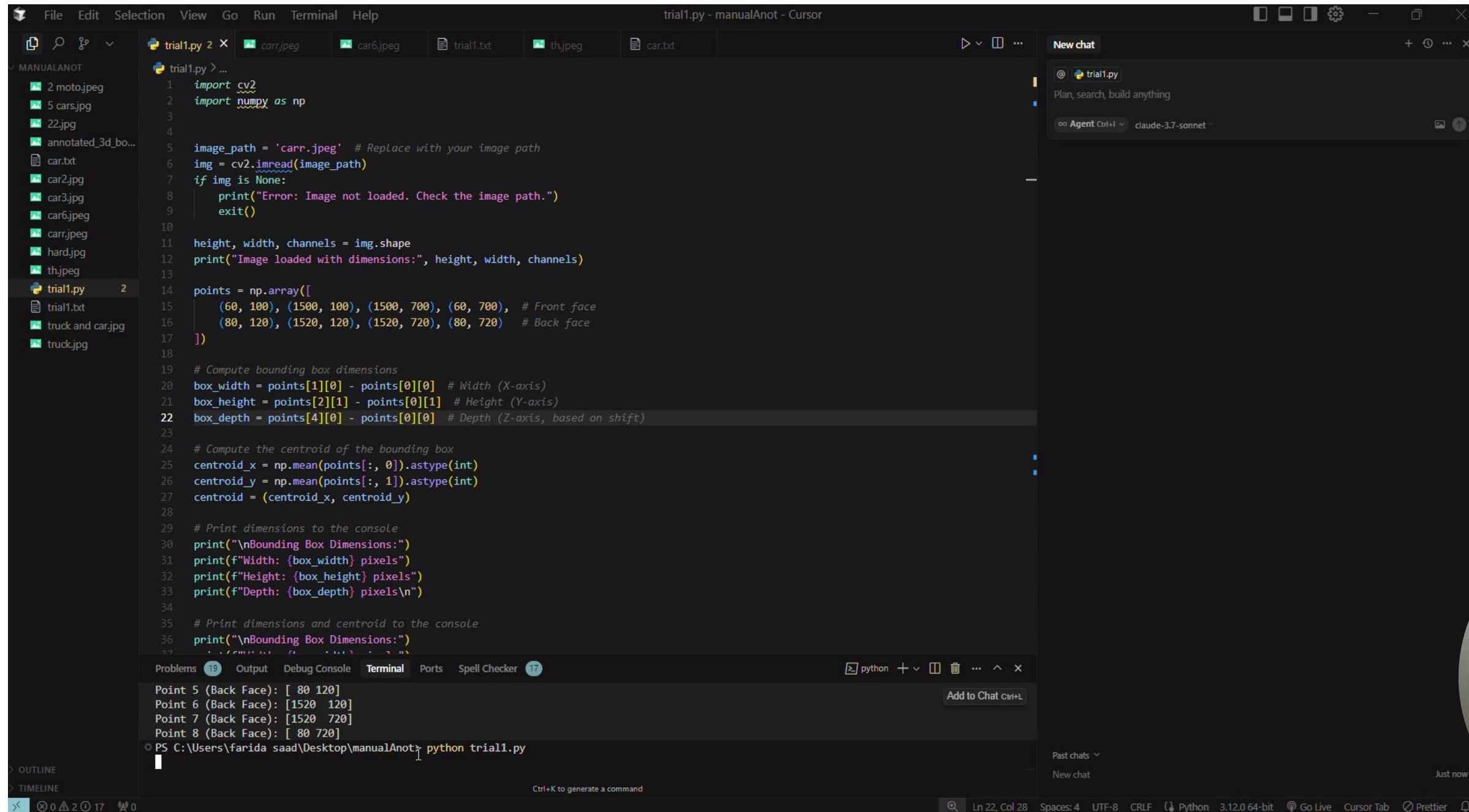
Here are some sample outputs showcasing both our automatic and manual annotation methods.

Yolo Detection (2D bounding boxes)



```
vehicle_detection_yolo.py 2 x yolo3D.py 9+ farida
1 import cv2
2 import numpy as np
3
4 # Load YOLO model
5 net = cv2.dnn.readNet('yolov3.weights', 'yolov3.cfg')
6 layer_names = net.getLayerNames()
7 output_layers = [layer_names[i - 1] for i in net.getUnconnectedOutLayers()]
8
9 # Load COCO class Labels
10 with open('coco.names', 'r')
11 ) as f:
12     classes = [line.strip() for line in f.readlines()]
13     print("Classes loaded:", classes)
14
15 # Load the image
16 image_path = '2ostrYarab.jpg' # Replace with your image path
17 img = cv2.imread(image_path)
18 if img is None:
19     print("Error: Image not loaded. Check the image path.")
20     exit()
21
22 height, width, channels = img.shape
23 print("Image loaded with dimensions:", height, width, channels)
24
25 # Prepare the image for YOLO
26 blob = cv2.dnn.blobFromImage(img, 0.00392, (416, 416), (0, 0, 0), True, crop=False)
27 net.setInput(blob)
28 outs = net.forward(output_layers)
29
30 # Initialize lists for detected class IDs, confidences, and bounding boxes
31 class_ids = []
32 confidences = []
33 boxes = []
34
35 # Process the output
36
37 PS C:\Users\farida saad\Desktop\demo1> python vehicle_detection_yolo.py
```

3D bounding boxes manual annotation using OpenCV



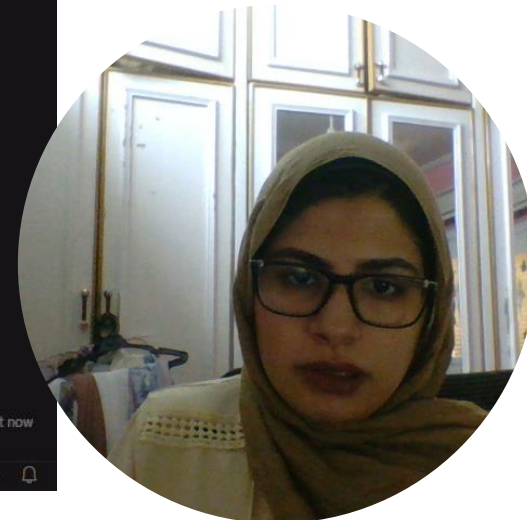
```
trial1.py > ...
1  import cv2
2  import numpy as np
3
4
5  image_path = 'carr.jpeg' # Replace with your image path
6  img = cv2.imread(image_path)
7  if img is None:
8      print("Error: Image not loaded. Check the image path.")
9      exit()
10
11 height, width, channels = img.shape
12 print("Image loaded with dimensions:", height, width, channels)
13
14 points = np.array([
15     (60, 100), (1500, 100), (1500, 700), (60, 700), # Front face
16     (80, 120), (1520, 120), (1520, 720), (80, 720) # Back face
17 ])
18
19 # Compute bounding box dimensions
20 box_width = points[1][0] - points[0][0] # Width (X-axis)
21 box_height = points[2][1] - points[0][1] # Height (Y-axis)
22 box_depth = points[4][0] - points[0][0] # Depth (Z-axis, based on shift)
23
24 # Compute the centroid of the bounding box
25 centroid_x = np.mean(points[:, 0]).astype(int)
26 centroid_y = np.mean(points[:, 1]).astype(int)
27 centroid = (centroid_x, centroid_y)
28
29 # Print dimensions to the console
30 print("\nBounding Box Dimensions:")
31 print(f"Width: {box_width} pixels")
32 print(f"Height: {box_height} pixels")
33 print(f"Depth: {box_depth} pixels\n")
34
35 # Print dimensions and centroid to the console
36 print("\nBounding Box Dimensions:")
37
```

Problems 19 Output Debug Console Terminal Ports Spell Checker 17

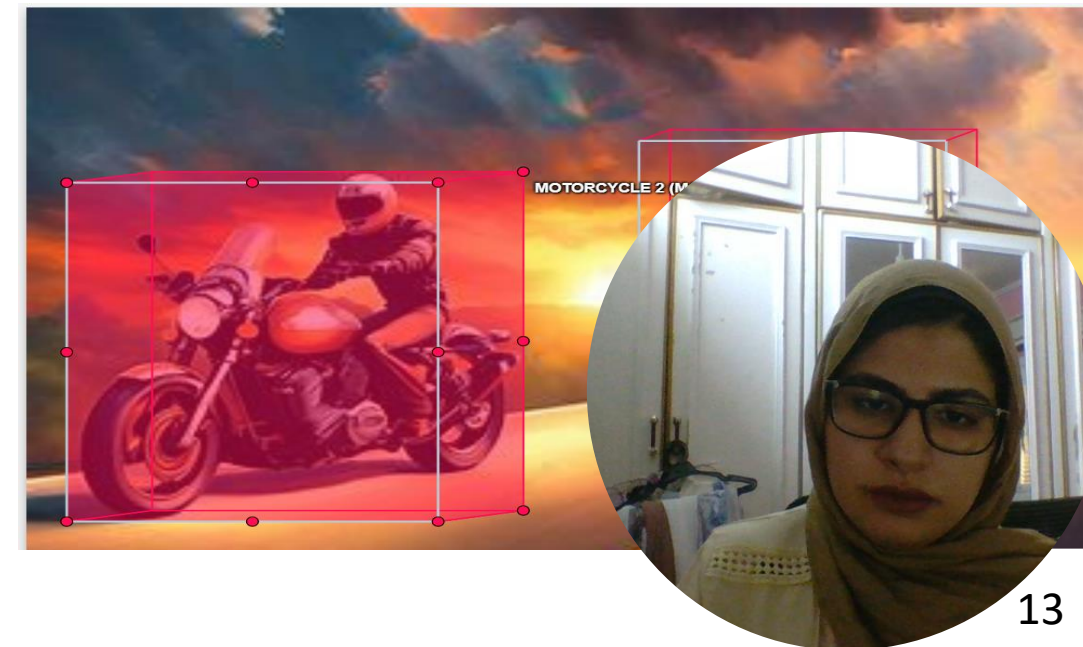
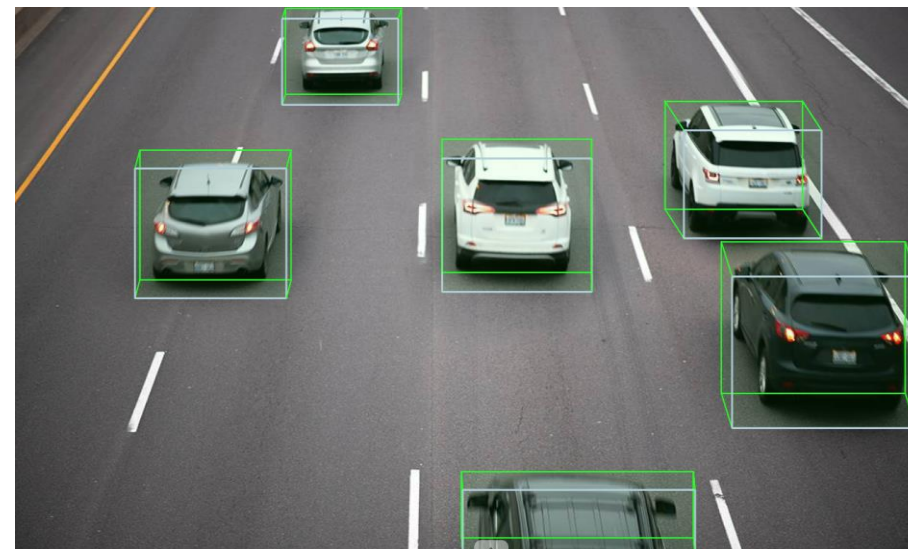
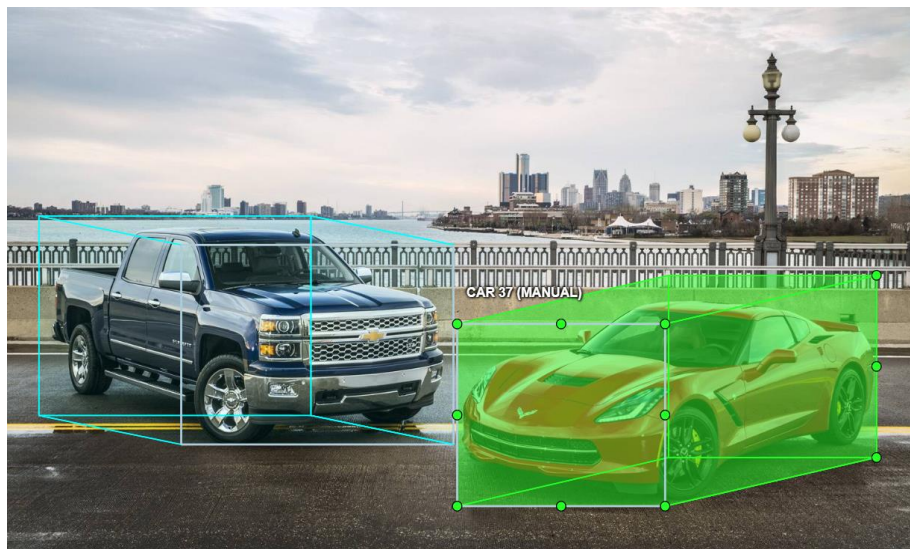
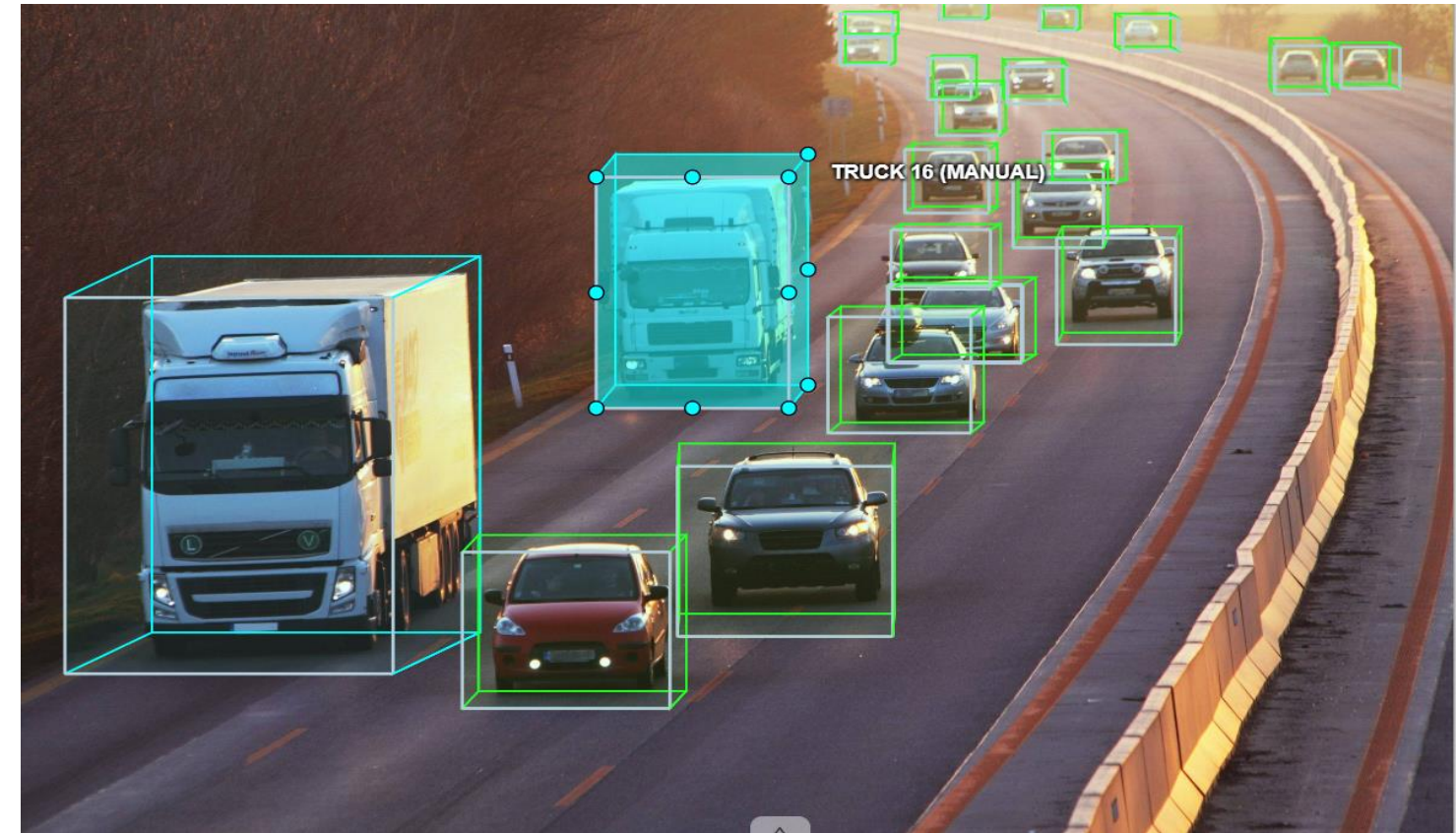
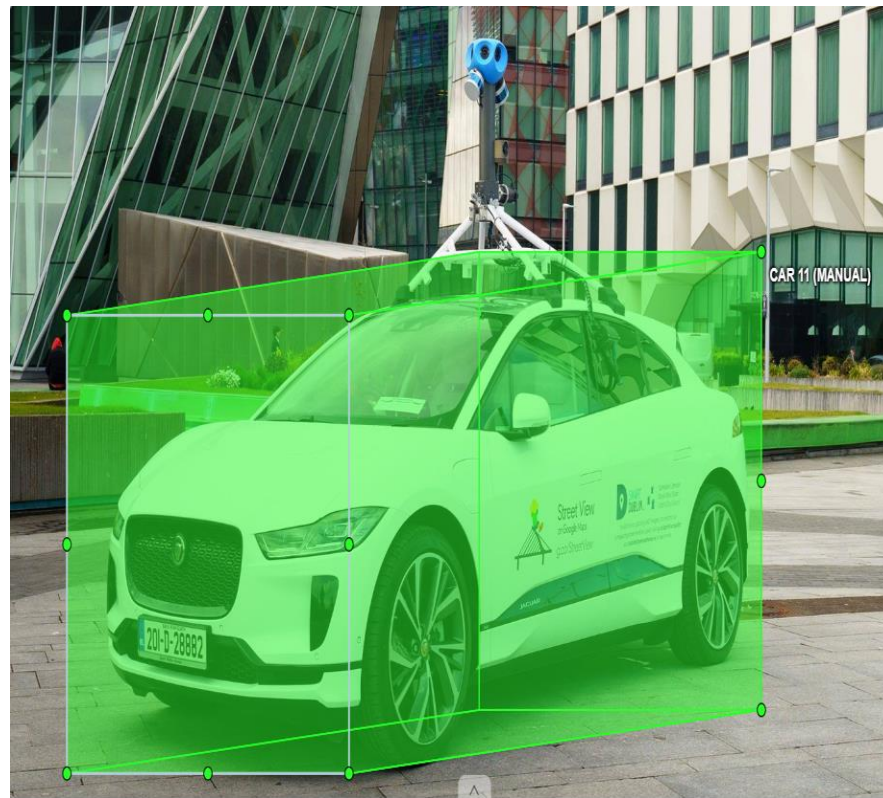
Point 5 (Back Face): [80 120]
Point 6 (Back Face): [1520 120]
Point 7 (Back Face): [1520 720]
Point 8 (Back Face): [80 720]

PS C:\Users\farida saad\Desktop>manualAnot> python trial1.py

Ln 22, Col 28 Spaces: 4 UTF-8 CRLF Python 3.12.0 64-bit Go Live Cursor Tab Prettier

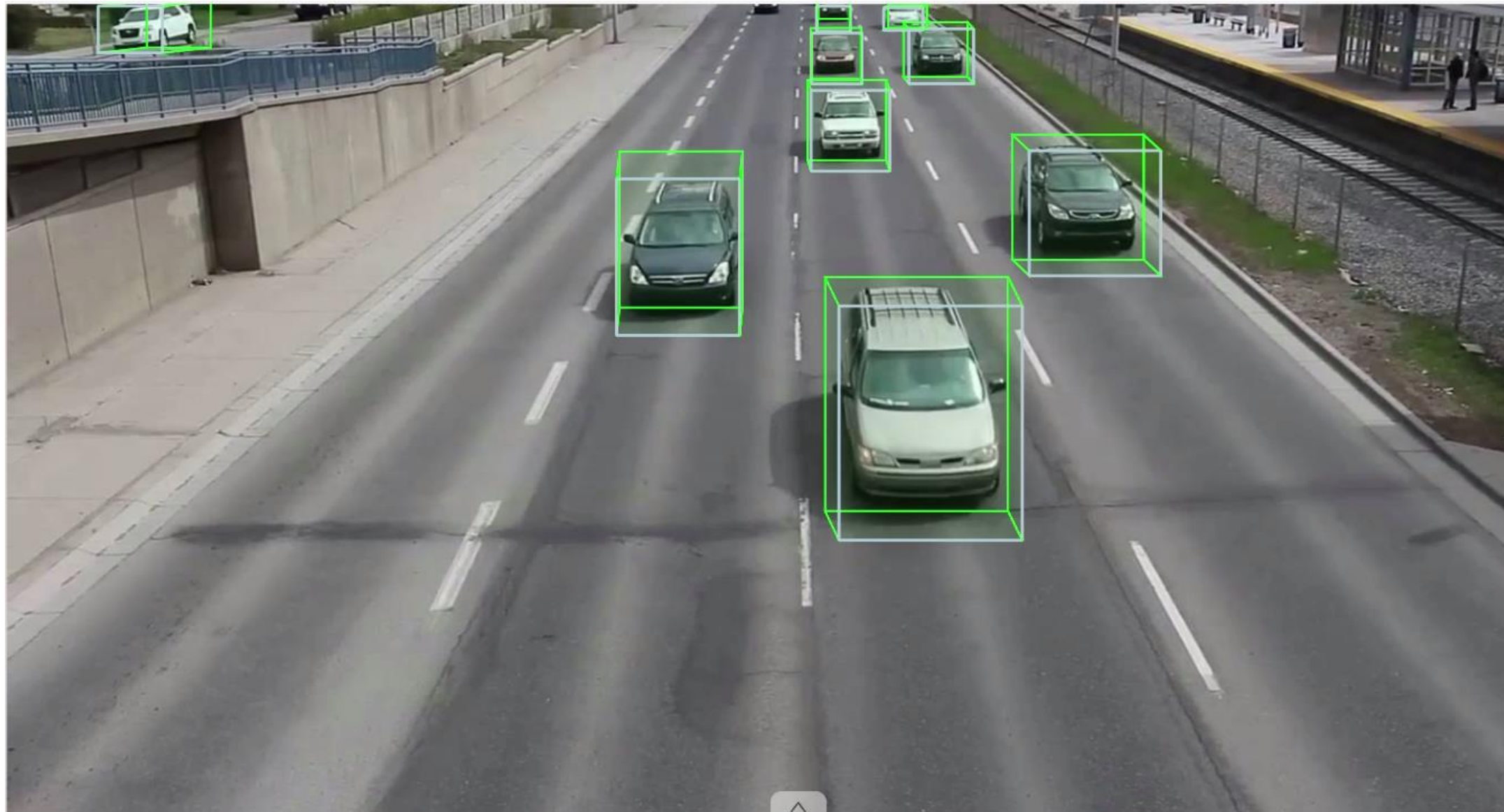


Annotated CVAT/Mindkosh Outputs

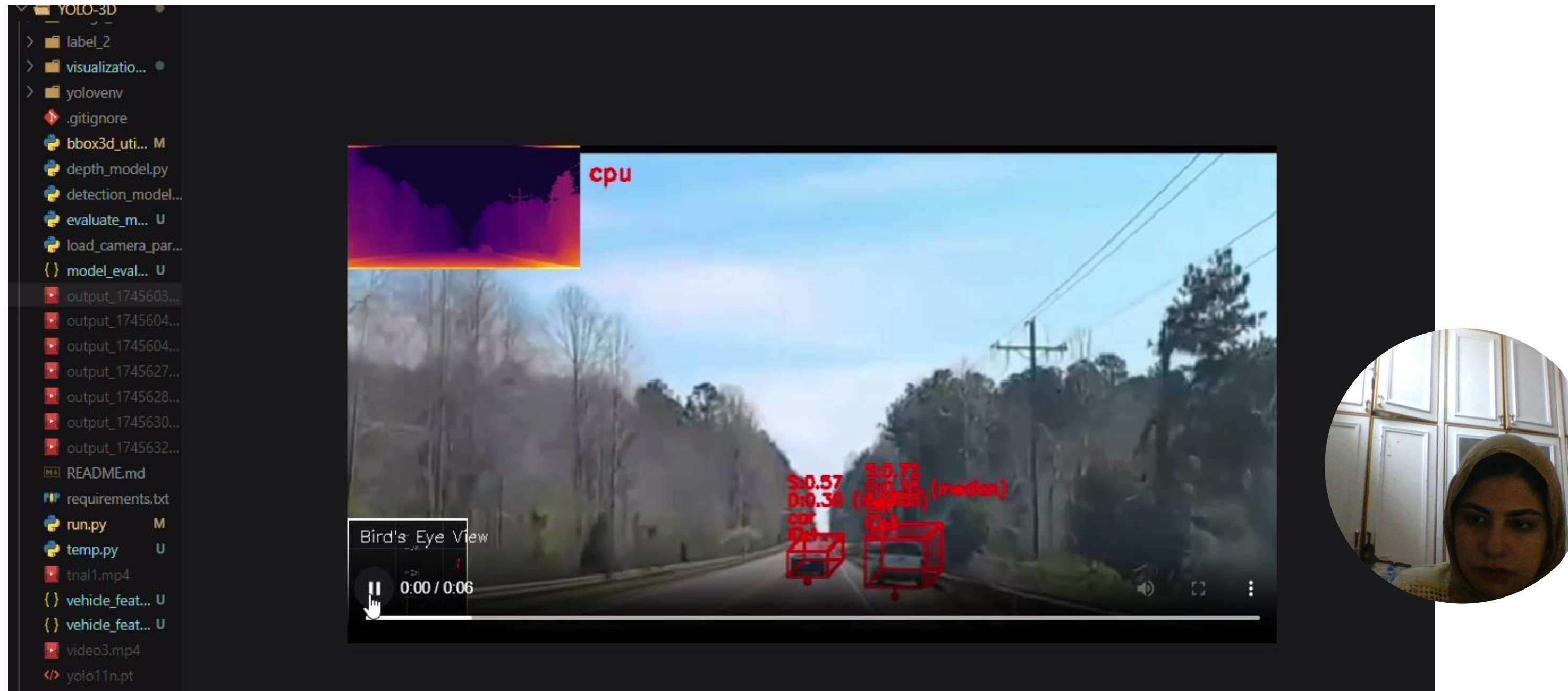


Annotated Video Results

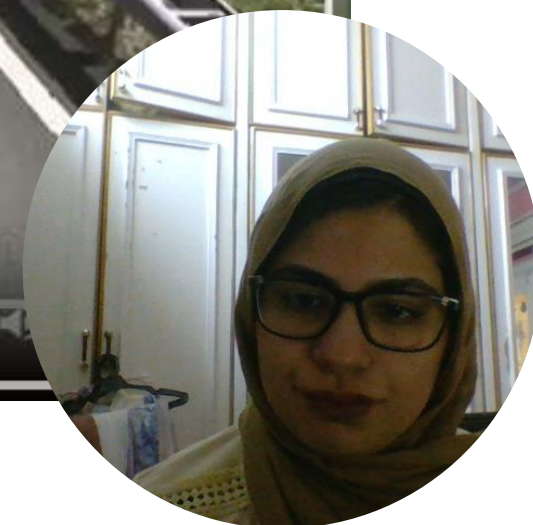
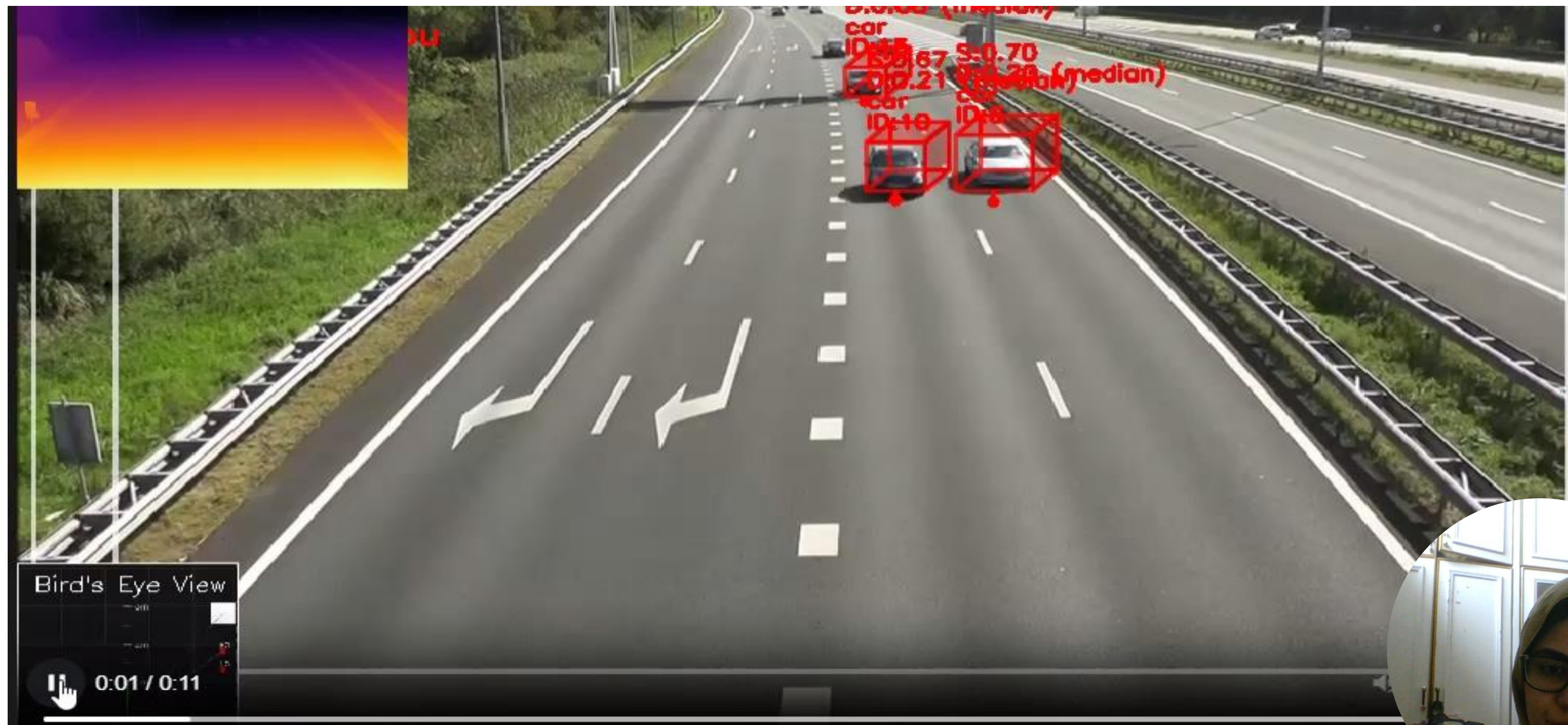
Here is the **60-frame video** I annotated. It shows the progress of labeling over 60 frames. Doing this frame-by-frame using the track features helps create high-quality training data for vehicle detection models.



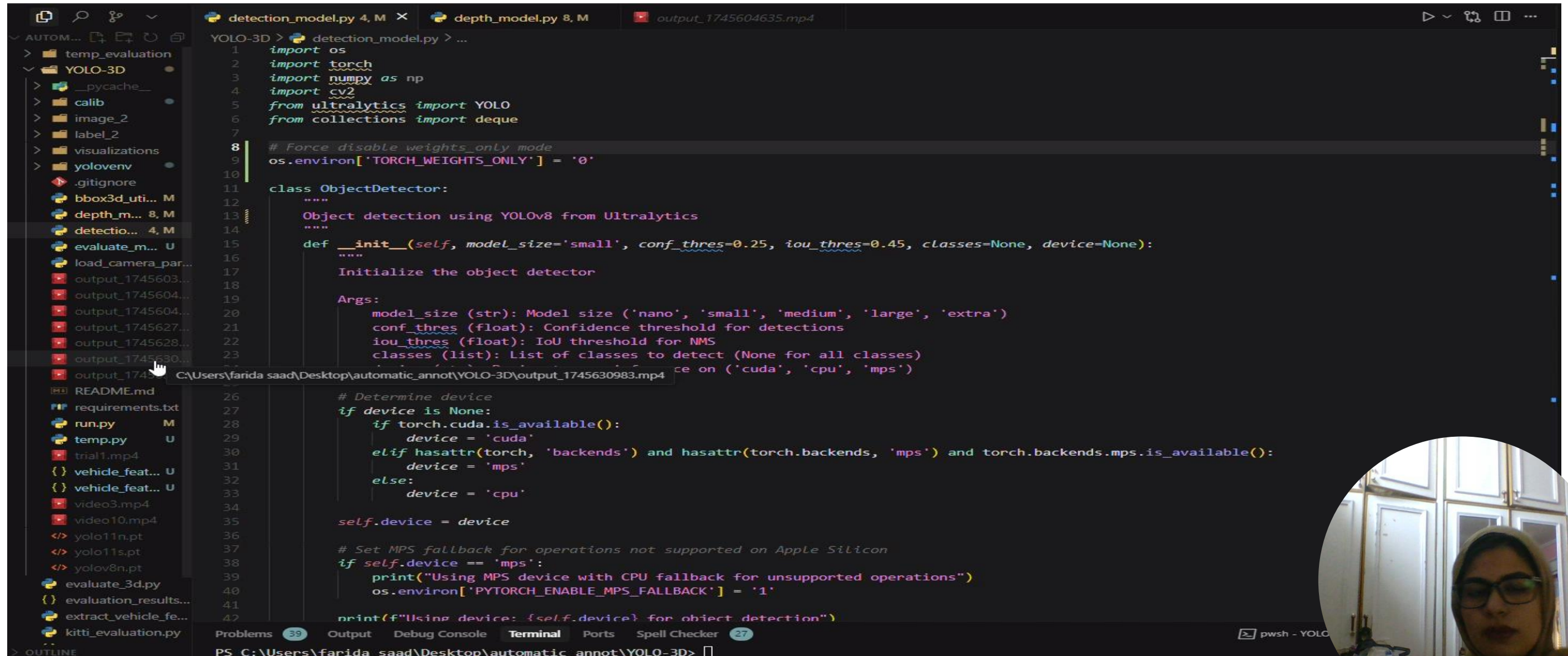
YOLOv11 and Depth Anything v2



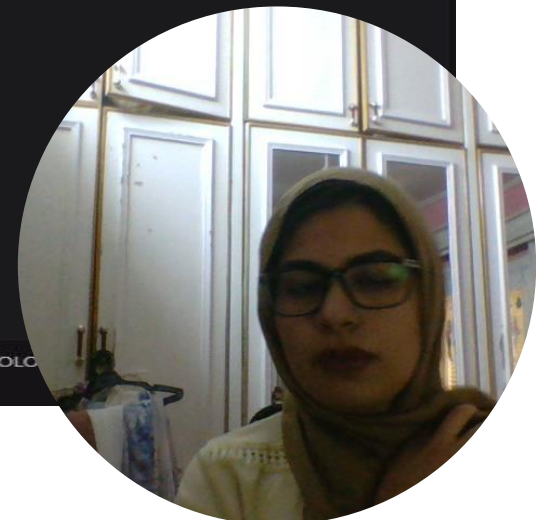
YOLOv11 and Depth Anything v2



YOLOv11 and Depth Anything v2 with annotations



```
1 import os
2 import torch
3 import numpy as np
4 import cv2
5 from ultralytics import YOLO
6 from collections import deque
7
8 # Force disable weights_only mode
9 os.environ['TORCH_WEIGHTS_ONLY'] = '0'
10
11 class ObjectDetector:
12     """
13     Object detection using YOLOv8 from Ultralytics
14     """
15     def __init__(self, model_size='small', conf_thres=0.25, iou_thres=0.45, classes=None, device=None):
16         """
17         Initialize the object detector
18
19         Args:
20             model_size (str): Model size ('nano', 'small', 'medium', 'large', 'extra')
21             conf_thres (float): Confidence threshold for detections
22             iou_thres (float): IoU threshold for NMS
23             classes (list): List of classes to detect (None for all classes)
24             device (str): Device to use for inference ('cuda', 'cpu', 'mps')
25
26         """
27         # Determine device
28         if device is None:
29             if torch.cuda.is_available():
30                 device = 'cuda'
31             elif hasattr(torch, 'backends') and hasattr(torch.backends, 'mps') and torch.backends.mps.is_available():
32                 device = 'mps'
33             else:
34                 device = 'cpu'
35
36         self.device = device
37
38         # Set MPS fallback for operations not supported on Apple Silicon
39         if self.device == 'mps':
40             print("Using MPS device with CPU fallback for unsupported operations")
41             os.environ['PYTORCH_ENABLE_MPS_FALLBACK'] = '1'
42
43     def __str__(self):
44         return f"Using device: {self.device} for object detection"
```



Features extracted

```
YOLO-3D > {} vehicle_features_1745628665.json > [ ] frames > {} 9 > {} vehicles > {} 6 > # closest_vehicle
1 {
2   "metadata": {
3     "source": "trial1.mp4",
4     "processed_frames": 335,
5     "fps": 29,
6     "resolution": "960x540",
7     "processing_time": 835.4210057258606,
8     "timestamp": 1745628665,
9     "velocity_scale": 2.5,
10    "smoothing_factor": 0.7
11  },
12  "frames": [
13    {
14      "frame": 0,
15      "timestamp": 4.836977481842041,
16      "vehicles": {}
17    },
18    {
19      "frame": 1,
20      "timestamp": 7.927078723907471,
21      "vehicles": {}
22    },
23    {
24      "frame": 2,
25      "timestamp": 10.037362098693848,
26      "vehicles": {}
27    },
28    {
29      "frame": 3,
30      "timestamp": 12.4356849193573,
31      "vehicles": {}
32    },
33    {
34      "frame": 4,
35      "timestamp": 14.732065677642822,
36      "vehicles": {}
37    },
38    {
39      "frame": 5,
40      "timestamp": 16.602839946746826,
41      "vehicles": {}
42    },
43    {
44      "frame": 6,
45      "timestamp": 18.473719675847371,
46      "vehicles": {}
47    },
48    {
49      "frame": 7,
50      "timestamp": 20.344609404948344,
51      "vehicles": {}
52    },
53    {
54      "frame": 8,
55      "timestamp": 22.215499134049483,
56      "vehicles": {}
57    },
58    {
59      "frame": 9,
60      "timestamp": 24.086388863150516,
61      "vehicles": {}
62    },
63    {
64      "frame": 10,
65      "timestamp": 25.957278592251549,
66      "vehicles": {}
67    },
68    {
69      "frame": 11,
70      "timestamp": 27.828168321352581,
71      "vehicles": {}
72    },
73    {
74      "frame": 12,
75      "timestamp": 29.699058050453614,
76      "vehicles": {}
77    },
78    {
79      "frame": 13,
80      "timestamp": 31.569947779554647,
81      "vehicles": {}
82    },
83    {
84      "frame": 14,
85      "timestamp": 33.44083750865568,
86      "vehicles": {}
87    },
88    {
89      "frame": 15,
90      "timestamp": 35.311727237756713,
91      "vehicles": {}
92    },
93    {
94      "frame": 16,
95      "timestamp": 37.182616966857746,
96      "vehicles": {}
97    },
98    {
99      "frame": 17,
100     "timestamp": 39.05350669595878,
101     "vehicles": {}
102    },
103    {
104      "frame": 18,
105      "timestamp": 40.924396425059813,
106      "vehicles": {}
107    },
108    {
109      "frame": 19,
110      "timestamp": 42.795286154160846,
111      "vehicles": {}
112    },
113    {
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115      "timestamp": 44.66617588326188,
116      "vehicles": {}
117    },
118    {
119      "frame": 21,
120      "timestamp": 46.537065612362913,
121      "vehicles": {}
122    },
123    {
124      "frame": 22,
125      "timestamp": 48.407955341463946,
126      "vehicles": {}
127    },
128    {
129      "frame": 23,
130      "timestamp": 50.27884507056498,
131      "vehicles": {}
132    },
133    {
134      "frame": 24,
135      "timestamp": 52.149734799666013,
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138    {
139      "frame": 25,
140      "timestamp": 54.020624528767046,
141      "vehicles": {}
142    },
143    {
144      "frame": 26,
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147    },
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157    },
158    {
159      "frame": 29,
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161      "vehicles": {}
162    },
163    {
164      "frame": 30,
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166      "vehicles": {}
167    },
168    {
169      "frame": 31,
170      "timestamp": 65.245962903373246,
171      "vehicles": {}
172    },
173    {
174      "frame": 32,
175      "timestamp": 67.11685263247428,
176      "vehicles": {}
177    },
178    {
179      "frame": 33,
180      "timestamp": 68.98774236157531,
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185      "timestamp": 70.85863209067635,
186      "vehicles": {}
187    },
188    {
189      "frame": 35,
190      "timestamp": 72.72952181977738,
191      "vehicles": {}
192    },
193    {
194      "frame": 36,
195      "timestamp": 74.60041154887841,
196      "vehicles": {}
197    },
198    {
199      "frame": 37,
200      "timestamp": 76.47130127797945,
201      "vehicles": {}
202    },
203    {
204      "frame": 38,
205      "timestamp": 78.34219100708048,
206      "vehicles": {}
207    },
208    {
209      "frame": 39,
210      "timestamp": 80.21308073618151,
211      "vehicles": {}
212    },
213    {
214      "frame": 40,
215      "timestamp": 82.08397046528255,
216      "vehicles": {}
217    },
218    {
219      "frame": 41,
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224      "frame": 42,
225      "timestamp": 85.82574992348461,
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227    },
228    {
229      "frame": 43,
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232    },
233    {
234      "frame": 44,
235      "timestamp": 89.56752938168668,
236      "vehicles": {}
237    },
238    {
239      "frame": 45,
240      "timestamp": 91.43841911078771,
241      "vehicles": {}
242    },
243    {
244      "frame": 46,
245      "timestamp": 93.30930883988875,
246      "vehicles": {}
247    },
248    {
249      "frame": 47,
250      "timestamp": 95.18019856898978,
251      "vehicles": {}
252    },
253    {
254      "frame": 48,
255      "timestamp": 97.05108829809081,
256      "vehicles": {}
257    },
258    {
259      "frame": 49,
260      "timestamp": 98.92197802719185,
261      "vehicles": {}
262    },
263    {
264      "frame": 50,
265      "timestamp": 100.79286775629288,
266      "vehicles": {}
267    },
268    {
269      "frame": 51,
270      "timestamp": 102.66375748539391,
271      "vehicles": {}
272    },
273    {
274      "frame": 52,
275      "timestamp": 104.53464721449495,
276      "vehicles": {}
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278    {
279      "frame": 53,
280      "timestamp": 106.40553694359598,
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282    },
283    {
284      "frame": 54,
285      "timestamp": 108.27642667269701,
286      "vehicles": {}
287    },
288    {
289      "frame": 55,
290      "timestamp": 110.14731640179805,
291      "vehicles": {}
292    },
293    {
294      "frame": 56,
295      "timestamp": 112.01820613089908,
296      "vehicles": {}
297    },
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Evaluation of YOLOv11 + Depth Anything v2

Evaluation Setup:

- Tested on a sampled subset of the KITTI dataset.
- Metrics used: Precision, Recall, Average Precision (AP).
- Focused classes: Cars, Trucks, Buses, and Other Road Users.

Detection Performance:

- Overall mAP: **6.8%**
- Car class:
 - **Precision:** 50.5%
 - **Recall:** 50.5%
 - **AP (car): 25.5%** (better performance achieved compared to Cursor baseline)



```
YOLO-3D / detection_model.py
1  import os
2  import torch
3  import numpy as np
4  import cv2
5  from ultralytics import YOLO
6  from collections import deque
7
8  # Force disable weights_only mode
9  os.environ['TORCH_WEIGHTS_ONLY'] = '0'
10
11  class ObjectDetector:
12      """
13      Object detection using YOLOv8 from Ultralytics
14      """
15      def __init__(self, model_size='small', conf_thres=0.25, iou_thres=0.45, classes=None, device=None):
16          """
17          Initialize the object detector
18
19          Args:
20              model_size (str): Model size ('nano', 'small', 'medium', 'large', 'extra')
21              conf_thres (float): Confidence threshold for detections
22              iou_thres (float): IoU threshold for NMS
23              classes (list): List of classes to detect (None for all classes)
24              device (str): Device to run inference on ('cuda', 'cpu', 'mps')
25          """
26          # Determine device
27          if device is None:
28              if torch.cuda.is_available():
29                  device = 'cuda'
30              elif hasattr(torch, 'backends') and hasattr(torch.backends, 'mps') and torch.backends.mps.is_available():
31                  device = 'mps'
32              else:
33                  device = 'cpu'
34
35          self.device = device
36
37          # Set MPS fallback for operations not supported on Apple Silicon
38          if self.device == 'mps':
39              print("Using MPS device with CPU fallback for unsupported operations")
40              os.environ['PYTORCH_ENABLE_MPS_FALLBACK'] = '1'
41
42          print(f"Using device: {self.device} for object detection")
```

Problems 39 Output Debug Console Terminal Ports Spell Checker 27

PS C:\Users\farida saad\Desktop\automatic_annot\YOLO-3D>



Current Pipeline Status

- **Automatic Annotation:**
 - Using YOLOv11 combined with Depth Anything v2 for real-time pseudo-3D bounding box generation.
- **Vehicle Feature Extraction:**
 - 3D bounding box dimensions and centroids
 - Orientation (yaw angle)
 - Lateral and longitudinal velocity and acceleration
 - Inter-vehicle distances
 - Occlusion levels (still working on it)
 - Time to Collision (TTC) (still working on it)
- **Automatic Annotation : (I'm Here)**
 - Training MonoLSS on the KITTI dataset for monocular 3D object detection.
 - Evaluating model performance using Average Precision 3D (AP3D) and Bird's Eye View Average Precision (APBEV).
- **Next Steps:**
 - Compare YOLOv11 + Depth Anything v2 with MonoLSS to select the best model for automatic annotation.



Conclusion



Developed an efficient vehicle-level feature annotation tool using monocular camera input.



Extracted critical vehicle features including velocity, acceleration, dimensions, and time-to-collision without using LiDAR or radar.



Demonstrated the feasibility of using real-time monocular models for detailed 3D object detection.



Future Recommendations

- **Enhance Feature Extraction:**
 - Refine extraction of occlusion and collision risk metrics.
- **Expand Dataset Size:**
 - Annotate longer video sequences and diverse traffic scenes to strengthen training data.
- **Explore Advanced Models:**
 - Investigate emerging monocular 3D detection models like YOLOBU or MonoFlex once accessible.
- **Automation Improvements:**
 - Develop a fully automatic pipeline minimizing manual intervention.
- **Generalization Testing:**
 - Test the trained pipeline across different datasets to ensure model robustness.



Any Questions?

Thank you for your time. I welcome any questions you may have.

