AAI521_Team6_Final_V5

December 11, 2023

1 AAI521-Final Project: Team 6

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##Edge IoT Device for Detecting and Counting People in a Region Of Interest ##

[ ]:
```
#@title 1: Install ultralytics for YOLO library
!pip install ultralytics
```

```
Requirement already satisfied: ultralytics in /usr/local/lib/python3.10/dist-
packages (8.0.226)
Requirement already satisfied: matplotlib>=3.3.0 in
/usr/local/lib/python3.10/dist-packages (from ultralytics) (3.7.1)
Requirement already satisfied: numpy>=1.22.2 in /usr/local/lib/python3.10/dist-
packages (from ultralytics) (1.23.5)
Requirement already satisfied: opencv-python>=4.6.0 in
/usr/local/lib/python3.10/dist-packages (from ultralytics) (4.8.0.76)
Requirement already satisfied: pillow>=7.1.2 in /usr/local/lib/python3.10/dist-
packages (from ultralytics) (9.4.0)
Requirement already satisfied: pyyaml>=5.3.1 in /usr/local/lib/python3.10/dist-
packages (from ultralytics) (6.0.1)
Requirement already satisfied: requests>=2.23.0 in
/usr/local/lib/python3.10/dist-packages (from ultralytics) (2.31.0)
Requirement already satisfied: scipy>=1.4.1 in /usr/local/lib/python3.10/dist-
packages (from ultralytics) (1.11.4)
Requirement already satisfied: torch>=1.8.0 in /usr/local/lib/python3.10/dist-
packages (from ultralytics) (2.1.0+cu118)
Requirement already satisfied: torchvision>=0.9.0 in
/usr/local/lib/python3.10/dist-packages (from ultralytics) (0.16.0+cu118)
Requirement already satisfied: tqdm>=4.64.0 in /usr/local/lib/python3.10/dist-
packages (from ultralytics) (4.66.1)
Requirement already satisfied: pandas>=1.1.4 in /usr/local/lib/python3.10/dist-
packages (from ultralytics) (1.5.3)
Requirement already satisfied: seaborn>=0.11.0 in
```

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/usr/local/lib/python3.10/dist-packages (from ultralytics) (0.12.2)
Requirement already satisfied: psutil in /usr/local/lib/python3.10/dist-packages
(from ultralytics) (5.9.5)
Requirement already satisfied: py-cpuinfo in /usr/local/lib/python3.10/dist-
packages (from ultralytics) (9.0.0)
Requirement already satisfied: thop>=0.1.1 in /usr/local/lib/python3.10/dist-
packages (from ultralytics) (0.1.1.post2209072238)
Requirement already satisfied: contourpy>=1.0.1 in
/usr/local/lib/python3.10/dist-packages (from matplotlib>=3.3.0->ultralytics)
(1.2.0)
Requirement already satisfied: cycler>=0.10 in /usr/local/lib/python3.10/dist-
packages (from matplotlib>=3.3.0->ultralytics) (0.12.1)
Requirement already satisfied: fonttools>=4.22.0 in
/usr/local/lib/python3.10/dist-packages (from matplotlib>=3.3.0->ultralytics)
(4.45.1)
Requirement already satisfied: kiwisolver>=1.0.1 in
/usr/local/lib/python3.10/dist-packages (from matplotlib>=3.3.0->ultralytics)
(1.4.5)
Requirement already satisfied: packaging>=20.0 in
/usr/local/lib/python3.10/dist-packages (from matplotlib>=3.3.0->ultralytics)
(23.2)
Requirement already satisfied: pyparsing>=2.3.1 in
/usr/local/lib/python3.10/dist-packages (from matplotlib>=3.3.0->ultralytics)
(3.1.1)
Requirement already satisfied: python-dateutil>=2.7 in
/usr/local/lib/python3.10/dist-packages (from matplotlib>=3.3.0->ultralytics)
(2.8.2)
Requirement already satisfied: pytz>=2020.1 in /usr/local/lib/python3.10/dist-
packages (from pandas>=1.1.4->ultralytics) (2023.3.post1)
Requirement already satisfied: charset-normalizer<4,>=2 in
/usr/local/lib/python3.10/dist-packages (from requests>=2.23.0->ultralytics)
(3.3.2)
Requirement already satisfied: idna<4,>=2.5 in /usr/local/lib/python3.10/dist-
packages (from requests>=2.23.0->ultralytics) (3.6)
Requirement already satisfied: urllib3<3,>=1.21.1 in
/usr/local/lib/python3.10/dist-packages (from requests>=2.23.0->ultralytics)
(2.0.7)
Requirement already satisfied: certifi>=2017.4.17 in
/usr/local/lib/python3.10/dist-packages (from requests>=2.23.0->ultralytics)
(2023.11.17)
Requirement already satisfied: filelock in /usr/local/lib/python3.10/dist-
packages (from torch>=1.8.0->ultralytics) (3.13.1)
Requirement already satisfied: typing-extensions in
/usr/local/lib/python3.10/dist-packages (from torch>=1.8.0->ultralytics) (4.5.0)
Requirement already satisfied: sympy in /usr/local/lib/python3.10/dist-packages
(from torch>=1.8.0->ultralytics) (1.12)
Requirement already satisfied: networkx in /usr/local/lib/python3.10/dist-
packages (from torch>=1.8.0->ultralytics) (3.2.1)
```

```
Requirement already satisfied: jinja2 in /usr/local/lib/python3.10/dist-packages
(from torch>=1.8.0->ultralytics) (3.1.2)
Requirement already satisfied: fsspec in /usr/local/lib/python3.10/dist-packages
(from torch>=1.8.0->ultralytics) (2023.6.0)
Requirement already satisfied: triton==2.1.0 in /usr/local/lib/python3.10/dist-
packages (from torch>=1.8.0->ultralytics) (2.1.0)
Requirement already satisfied: six>=1.5 in /usr/local/lib/python3.10/dist-
packages (from python-dateutil>=2.7->matplotlib>=3.3.0->ultralytics) (1.16.0)
Requirement already satisfied: MarkupSafe>=2.0 in
/usr/local/lib/python3.10/dist-packages (from jinja2->torch>=1.8.0->ultralytics)
(2.1.3)
Requirement already satisfied: mpmath>=0.19 in /usr/local/lib/python3.10/dist-
packages (from sympy->torch>=1.8.0->ultralytics) (1.3.0)
```

[ ]:
```python
#@title 1.1: Loading related libraries
import cv2
from ultralytics import YOLO

import matplotlib.pyplot as plt

import pandas as pd
import numpy as np
import os
import subprocess
from tqdm.notebook import tqdm

from IPython.display import Video, display, HTML, Javascript, Image
import datetime

from base64 import b64encode, b64decode

from google.colab.output import eval_js
from google.colab.patches import cv2_imshow

from google.colab import drive
drive.mount('/content/drive')
```

```
Drive already mounted at /content/drive; to attempt to forcibly remount, call
drive.mount("/content/drive", force_remount=True).
```

[ ]:
```python
#@title 2: Loading a YOLO model
model = YOLO('yolov8x.pt')

# Enhance the YOLO model with additional knowledge transfer to help with unique␣
 ↪lighting or busy ROI
model.train(data="coco128.yaml", epochs=3)  # train the model
```

```python
#geting names from classes
dict_classes = model.model.names
```

```
Ultralytics YOLOv8.0.226  Python-3.10.12 torch-2.1.0+cu118 CUDA:0 (Tesla T4,
15102MiB)
engine/trainer: task=detect, mode=train, model=yolov8x.pt,
data=coco128.yaml, epochs=3, patience=50, batch=16, imgsz=640, save=True,
save_period=-1, cache=False, device=None, workers=8, project=None, name=train2,
exist_ok=False, pretrained=True, optimizer=auto, verbose=True, seed=0,
deterministic=True, single_cls=False, rect=False, cos_lr=False, close_mosaic=10,
resume=False, amp=True, fraction=1.0, profile=False, freeze=None,
overlap_mask=True, mask_ratio=4, dropout=0.0, val=True, split=val,
save_json=False, save_hybrid=False, conf=None, iou=0.7, max_det=300, half=False,
dnn=False, plots=True, source=None, vid_stride=1, stream_buffer=False,
visualize=False, augment=False, agnostic_nms=False, classes=None,
retina_masks=False, show=False, save_frames=False, save_txt=False,
save_conf=False, save_crop=False, show_labels=True, show_conf=True,
show_boxes=True, line_width=None, format=torchscript, keras=False,
optimize=False, int8=False, dynamic=False, simplify=False, opset=None,
workspace=4, nms=False, lr0=0.01, lrf=0.01, momentum=0.937, weight_decay=0.0005,
warmup_epochs=3.0, warmup_momentum=0.8, warmup_bias_lr=0.1, box=7.5, cls=0.5,
dfl=1.5, pose=12.0, kobj=1.0, label_smoothing=0.0, nbs=64, hsv_h=0.015,
hsv_s=0.7, hsv_v=0.4, degrees=0.0, translate=0.1, scale=0.5, shear=0.0,
perspective=0.0, flipud=0.0, fliplr=0.5, mosaic=1.0, mixup=0.0, copy_paste=0.0,
cfg=None, tracker=botsort.yaml, save_dir=runs/detect/train2

                   from  n    params  module
arguments
  0                  -1  1      2320  ultralytics.nn.modules.conv.Conv
[3, 80, 3, 2]
  1                  -1  1    115520  ultralytics.nn.modules.conv.Conv
[80, 160, 3, 2]
  2                  -1  3    436800  ultralytics.nn.modules.block.C2f
[160, 160, 3, True]
  3                  -1  1    461440  ultralytics.nn.modules.conv.Conv
[160, 320, 3, 2]
  4                  -1  6   3281920  ultralytics.nn.modules.block.C2f
[320, 320, 6, True]
  5                  -1  1   1844480  ultralytics.nn.modules.conv.Conv
[320, 640, 3, 2]
  6                  -1  6  13117440  ultralytics.nn.modules.block.C2f
[640, 640, 6, True]
  7                  -1  1   3687680  ultralytics.nn.modules.conv.Conv
[640, 640, 3, 2]
  8                  -1  3   6969600  ultralytics.nn.modules.block.C2f
[640, 640, 3, True]
  9                  -1  1   1025920  ultralytics.nn.modules.block.SPPF
```

```
[640, 640, 5]
 10                  -1  1         0  torch.nn.modules.upsampling.Upsample
[None, 2, 'nearest']
 11             [-1, 6]  1         0  ultralytics.nn.modules.conv.Concat
[1]
 12                  -1  3   7379200  ultralytics.nn.modules.block.C2f
[1280, 640, 3]
 13                  -1  1         0  torch.nn.modules.upsampling.Upsample
[None, 2, 'nearest']
 14             [-1, 4]  1         0  ultralytics.nn.modules.conv.Concat
[1]
 15                  -1  3   1948800  ultralytics.nn.modules.block.C2f
[960, 320, 3]
 16                  -1  1    922240  ultralytics.nn.modules.conv.Conv
[320, 320, 3, 2]
 17            [-1, 12]  1         0  ultralytics.nn.modules.conv.Concat
[1]
 18                  -1  3   7174400  ultralytics.nn.modules.block.C2f
[960, 640, 3]
 19                  -1  1   3687680  ultralytics.nn.modules.conv.Conv
[640, 640, 3, 2]
 20             [-1, 9]  1         0  ultralytics.nn.modules.conv.Concat
[1]
 21                  -1  3   7379200  ultralytics.nn.modules.block.C2f
[1280, 640, 3]
 22        [15, 18, 21]  1   8795008  ultralytics.nn.modules.head.Detect
[80, [320, 640, 640]]
Model summary: 365 layers, 68229648 parameters, 68229632 gradients, 258.5 GFLOPs

Transferred 595/595 items from pretrained weights
TensorBoard: Start with 'tensorboard --logdir runs/detect/train2',
view at http://localhost:6006/
Freezing layer 'model.22.dfl.conv.weight'
AMP: running Automatic Mixed Precision (AMP) checks with YOLOv8n…
AMP: checks passed

train: Scanning /content/datasets/coco128/labels/train2017.cache…
126 images, 2 backgrounds, 0 corrupt: 100%|      | 128/128 [00:00<?, ?it/s]

albumentations: Blur(p=0.01, blur_limit=(3, 7)), MedianBlur(p=0.01,
blur_limit=(3, 7)), ToGray(p=0.01), CLAHE(p=0.01, clip_limit=(1, 4.0),
tile_grid_size=(8, 8))

val: Scanning /content/datasets/coco128/labels/train2017.cache…
126 images, 2 backgrounds, 0 corrupt: 100%|      | 128/128 [00:00<?, ?it/s]

Plotting labels to runs/detect/train2/labels.jpg…
optimizer: 'optimizer=auto' found, ignoring 'lr0=0.01' and
'momentum=0.937' and determining best 'optimizer', 'lr0' and 'momentum'
automatically…
```

```
optimizer: AdamW(lr=0.000119, momentum=0.9) with parameter groups
97 weight(decay=0.0), 104 weight(decay=0.0005), 103 bias(decay=0.0)
Image sizes 640 train, 640 val
Using 2 dataloader workers
Logging results to runs/detect/train2
Starting training for 3 epochs…

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size

        1/3      13.8G     0.8623     0.8033      1.156        228        640:
100%|      | 8/8 [00:11<00:00,  1.44s/it]
                 Class     Images  Instances      Box(P          R      mAP50
mAP50-95): 100%|      | 4/4 [00:03<00:00,  1.12it/s]

                   all        128        929      0.816      0.733      0.833
0.669



      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size

        2/3      14.3G     0.8665     0.6925       1.13        151        640:
100%|      | 8/8 [00:10<00:00,  1.29s/it]
                 Class     Images  Instances      Box(P          R      mAP50
mAP50-95): 100%|      | 4/4 [00:03<00:00,  1.11it/s]

                   all        128        929      0.877      0.746      0.855
0.69



      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size

        3/3      14.3G     0.8381     0.6663      1.119        164        640:
100%|      | 8/8 [00:10<00:00,  1.28s/it]
                 Class     Images  Instances      Box(P          R      mAP50
mAP50-95): 100%|      | 4/4 [00:04<00:00,  1.01s/it]

                   all        128        929      0.875      0.758       0.85
0.688



3 epochs completed in 0.018 hours.
Optimizer stripped from runs/detect/train2/weights/last.pt, 136.9MB
Optimizer stripped from runs/detect/train2/weights/best.pt, 136.9MB

Validating runs/detect/train2/weights/best.pt…
Ultralytics YOLOv8.0.226  Python-3.10.12 torch-2.1.0+cu118 CUDA:0 (Tesla T4,
15102MiB)
```

```
Model summary (fused): 268 layers, 68200608 parameters, 0 gradients, 257.8
GFLOPs
                 Class     Images  Instances      Box(P          R      mAP50
mAP50-95): 100%|      | 4/4 [00:07<00:00,  1.77s/it]
                   all        128        929      0.877      0.746      0.854
0.689
                person        128        254      0.951      0.705      0.887
0.688
               bicycle        128          6      0.776      0.667      0.739
0.597
                   car        128         46          1       0.39      0.673
0.374
            motorcycle        128          5      0.987          1      0.995
0.812
              airplane        128          6      0.953          1      0.995
0.933
                   bus        128          7      0.897      0.714      0.864
0.768
                 train        128          3      0.877          1      0.995
0.995
                 truck        128         12      0.784      0.417      0.682
0.47
                  boat        128          6          1       0.59      0.816
0.573
         traffic light        128         14          1      0.337      0.544
0.325
             stop sign        128          2      0.875          1      0.995
0.995
                 bench        128          9          1      0.629      0.852
0.636
                  bird        128         16      0.967          1      0.995
0.695
                   cat        128          4      0.906          1      0.995
0.924
                   dog        128          9      0.894      0.942      0.984
0.912
                 horse        128          2      0.854          1      0.995
0.799
              elephant        128         17      0.967      0.941      0.953
0.851
                  bear        128          1      0.765          1      0.995
0.995
                 zebra        128          4      0.908          1      0.995
0.995
               giraffe        128          9      0.948          1      0.995
0.825
              backpack        128          6          1      0.638      0.752
```

						0.528
umbrella	128	18	0.954	0.833	0.943	0.704
handbag	128	19	0.838	0.546	0.699	0.5
tie	128	7	1	0.792	0.86	0.766
suitcase	128	4	0.933	1	0.995	0.648
frisbee	128	5	0.787	0.8	0.806	0.731
skis	128	1	0.809	1	0.995	0.796
snowboard	128	7	0.941	0.857	0.864	0.821
sports ball	128	6	0.633	0.584	0.535	0.361
kite	128	10	0.949	0.4	0.513	0.18
baseball bat	128	4	0.989	1	0.995	0.592
baseball glove	128	7	0.657	0.429	0.401	0.293
skateboard	128	5	0.614	0.6	0.762	0.548
tennis racket	128	7	1	0.699	0.721	0.412
bottle	128	18	0.668	0.447	0.706	0.485
wine glass	128	16	0.972	0.5	0.71	0.536
cup	128	36	0.928	0.717	0.924	0.681
fork	128	6	0.742	0.5	0.725	0.538
knife	128	16	0.915	0.675	0.896	0.618
spoon	128	22	0.885	0.636	0.753	0.633
bowl	128	28	0.874	0.786	0.831	0.732
banana	128	1	1	0	0.995	0.995
sandwich	128	2	0.808	1	0.995	0.995
orange	128	4	0.611	1	0.912	0.717
broccoli	128	11	1	0.366	0.592	

						0.451
carrot	128	24	0.826	0.792	0.875	0.671
hot dog	128	2	0.851	1	0.995	0.995
pizza	128	5	0.882	1	0.995	0.882
donut	128	14	0.776	1	0.995	0.933
cake	128	4	0.86	1	0.995	0.905
chair	128	35	0.715	0.743	0.828	0.596
couch	128	6	0.991	1	0.995	0.853
potted plant	128	14	0.892	0.591	0.889	0.717
bed	128	3	0.92	1	0.995	0.805
dining table	128	13	1	0.715	0.872	0.796
toilet	128	2	0.912	1	0.995	0.739
tv	128	2	0.817	1	0.995	0.895
laptop	128	3	0.616	0.667	0.863	0.792
mouse	128	2	1	0	0.663	0.333
remote	128	8	1	0.66	0.762	0.659
cell phone	128	8	0.969	0.625	0.697	0.436
microwave	128	3	0.917	1	0.995	0.93
oven	128	5	0.537	0.4	0.298	0.233
sink	128	6	0.667	0.5	0.643	0.514
refrigerator	128	5	0.878	1	0.995	0.845
book	128	29	0.772	0.414	0.562	0.35
clock	128	9	0.956	0.889	0.975	0.831
vase	128	2	0.797	1	0.995	0.995
scissors	128	1	1	0	0.995	

```
0.199
            teddy bear        128         21      0.964      0.857      0.977
0.72
            toothbrush        128          5      0.921          1      0.995
0.868
Speed: 1.1ms preprocess, 23.2ms inference, 0.0ms loss, 2.7ms postprocess per
image
Results saved to runs/detect/train2
```

[ ]:
```python
#@title 2.1: Load video (emulate capture)
# Load video (emulate capture)
video_name = 'City_Hall-IOT1'
encoding_type = '.mp4'
video_folder = '/content/drive/MyDrive/AAI-521/Final/Test/'

video_path = video_folder + video_name + encoding_type
video = cv2.VideoCapture(video_path)
```

[ ]:
```python
#@title 3: Define required functions for video processing
# process frames
def risize_frame(frame, scale_percent):
    """Function to resize frame"""
    # resize image
    width = int(frame.shape[1] * scale_percent / 100)
    height = int(frame.shape[0] * scale_percent / 100)
    dim = (width, height)
    # resize image
    resized = cv2.resize(frame, dim, interpolation = cv2.INTER_AREA)
    return resized

# Filter the history of tracked objects
def filter_tracks(centers, patience):
    """Function to filter the history of tracked objects"""
    filter_dict = {}
    for k, i in centers.items():
        d_frames = i.items()
        filter_dict[k] = dict(list(d_frames)[-patience:])

    return filter_dict

# Update tracked objects
def update_tracking(centers_old,obj_center, thr_centers, lastKey, frame,␣
 ↪frame_max):
    is_new = 0 # Reset count
    lastpos = [(k, list(center.keys())[-1], list(center.values())[-1]) for k,␣
 ↪center in centers_old.items()]
```

```
    lastpos = [(i[0], i[2]) for i in lastpos if abs(i[1] - frame) <= frame_max]␣
↪# Check position within each frame
    # Calculating distance from existing centers points - calculate if same or␣
↪new person
    previous_pos = [(k,obj_center) for k,centers in lastpos if (np.linalg.
↪norm(np.array(centers) - np.array(obj_center)) < thr_centers)]
    # if distance less than a threshold, it will update its positions
    if previous_pos:
        id_obj = previous_pos[0][0]
        centers_old[id_obj][frame] = obj_center

    # Else a new ID will be set to the given object
    else:
        if lastKey:
            last = lastKey.split('D')[1]
            id_obj = 'ID' + str(int(last)+1)
        else:
            id_obj = 'ID0'

        is_new = 1
        centers_old[id_obj] = {frame:obj_center}
        lastKey = list(centers_old.keys())[-1]

    return centers_old, id_obj, is_new, lastKey

def plt_pretty_image(image, label=None):
    """Function to display an image using matplotlib.pyplot.imshow with plt␣
↪graphing features (Grid and x/y ticks removed)"""
    plt.xticks([])
    plt.yticks([])
    plt.grid(False)
    plt.imshow(image, cmap='gray')
    plt.xlabel(label)

def video_to_base64(file_path):
    with open(file_path, 'rb') as video_file:
        encoded_string = b64encode(video_file.read()).decode()
    return encoded_string
```

[ ]:
```
#@title 3.1: Configurations for ROI objects

# Scaling percentage of original frame
scale_percent = 100
# model confidence level
conf_level = 0.6
# Threshold of centers ( old\new)
thr_centers = 30 # Pixles between objects (modify per test MP4)
```

```
#Number of max frames to consider a object lost
frame_max = 5
# Number of max tracked centers stored
patience = 100
# ROI area color transparency
alpha = 0.2
```

[ ]:
```
#@title 4.1: Set person class to detect in YOLO
# Objects to detect Yolo
class_IDS = [0] #Persons

# Auxiliary variables
centers_old = {}
obj_id = 0
end = []
frames_list = []
count_p = 0
lastKey = ''
```

[ ]:
```
#@title 4.2: Settings for input of video
# Original informations of video
height = int(video.get(cv2.CAP_PROP_FRAME_HEIGHT))
width = int(video.get(cv2.CAP_PROP_FRAME_WIDTH))
fps = video.get(cv2.CAP_PROP_FPS)
frame_count = int(video.get(cv2.CAP_PROP_FRAME_COUNT))
print(f'Original dimensions: {(width, height)}')
print(f'Original FPS: {fps}')

# Scaling Video for better performance
if scale_percent != 100:
    print('Scaling change may cause errors in pixels lines ')
    width = int(width * scale_percent / 100)
    height = int(height * scale_percent / 100)
    print(f'Dimension scaled: {(width, height)}')
```

```
Original dimensions: (1920, 1080)
Original FPS: 25.0
```

[ ]:
```
#@title 4.3: Settings on video output
# Settings for video output
output_video_path = video_name + '_result.mp4'
VIDEO_CODEC = "MP4V" #set to MP4 codec
tmp_output_path = 'tmp_' + output_video_path

fourcc = cv2.VideoWriter_fourcc(*VIDEO_CODEC)
output_video = cv2.VideoWriter(
    tmp_output_path,
    fourcc=fourcc,
    fps=fps,
    frameSize=(width, height)
)
```

[ ]:
```
#@title 4.4 ROI area setup
custom_roi = False

# default full frame
if not custom_roi:
    x_min = 0
    x_max = x_min + width
    y_min = 0
    y_max = y_min + height
else:
    x_min = 100
    x_max = 500
    y_min = 50
    y_max = 300

blur_factor = 0

# font scaling
font_size = min(width, height) // 300
font_thickness = max(6, font_size // 2)
```

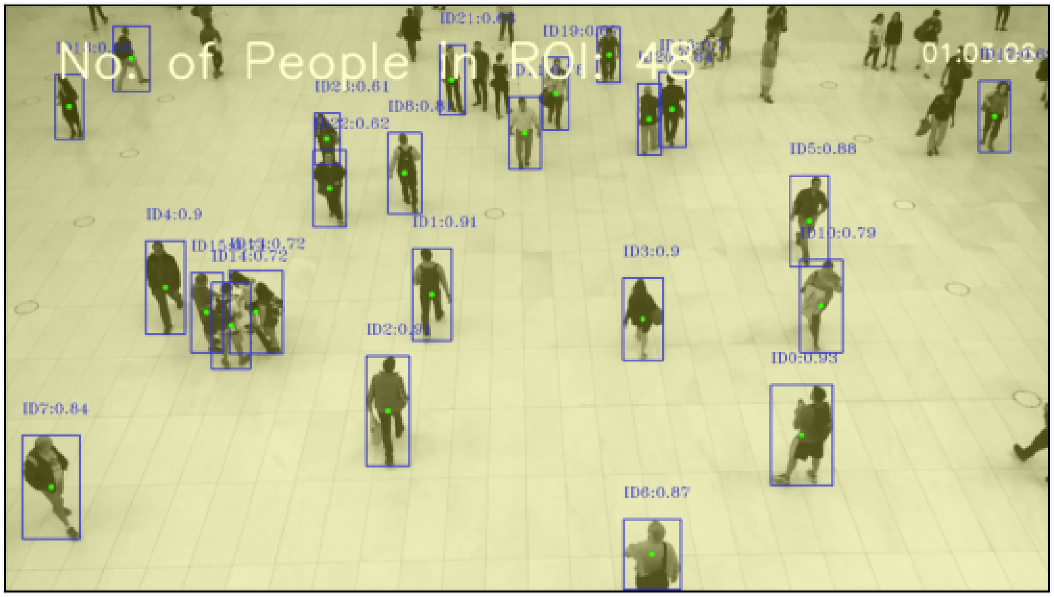
[ ]:
```
#@title 5: Executing Recognition in an ROI section

# Initialize DataFrame to store results
results_df = pd.DataFrame(columns=['Frame', 'Timestamp', 'People_Count',␣
 ↪'Confidence_Scores'])

for i in tqdm(range(frame_count)):

    # reading frame from video
    ret, frame = video.read()

    if not ret:
        continue

    # Applying resizing of read frame
    if scale_percent != 100:
        frame  = risize_frame(frame, scale_percent)

    # Apply Gaussian Blur to the frame
    frame = cv2.cvtColor(frame, cv2.COLOR_BGR2RGB)
    frame = cv2.GaussianBlur(frame, (3, 3), blur_factor)
    # Setup ROI
    area_roi = [np.
↪array([(x_min,y_min),(x_min,y_max),(x_max,y_max),(x_max,y_min)], np.int32)]
    roi_frame = frame[y_min:y_max, x_min:x_max]

    # Getting predictions
    y_hat = model.predict(roi_frame, conf = conf_level, classes = class_IDS,␣
↪device = 0, verbose = False)

    # Update total count of people
    count_p = 0
    confidence_scores = [] #Set for Excel output

    # Fetch current time
    current_time = datetime.datetime.now()
    time_str = current_time.strftime("%H:%M:%S")  # Format time as HH:MM:SS

    text_size = cv2.getTextSize(time_str, cv2.FONT_HERSHEY_SIMPLEX, font_size/
↪2, font_thickness//2)[0]
    text_x = int(frame.shape[1] - text_size[0] - (frame.shape[1] * 0.01))
    text_y = int(frame.shape[0] * 0.1)

    cv2.putText(frame, time_str, (text_x, text_y),
                cv2.FONT_HERSHEY_SIMPLEX, font_size/2, (255, 255, 255),␣
↪font_thickness//2)

    # Getting the bounding boxes, confidence and classes of the recognize␣
↪objects in the current frame.
    boxes_data = y_hat[0].boxes.xyxy.cpu().numpy() #Move into CPU memory
    confidences = y_hat[0].boxes.conf.cpu().numpy()
    classes = y_hat[0].boxes.cls.cpu().numpy()

    # Storing the above information in a dataframe, setting the min and max␣
↪values
    positions_frame = pd.DataFrame(boxes_data, columns=['xmin', 'ymin', 'xmax',␣
↪'ymax'])
    positions_frame['conf'] = confidences
    positions_frame['class'] = classes

    #Translating the numeric class labels to text
    labels = [dict_classes[i] for i in classes]

    #handle tracking logic
    for ix, row in enumerate(positions_frame.iterrows()):
        xmin, ymin, xmax, ymax, confidence, category = row[1].astype('int')
        count_p += 1

        confidence_scores.append(confidence) #Append data for Excel file
        # Calculating the center of the bounding box
        center_x, center_y = int(((xmax + xmin) / 2)), int(((ymax + ymin) / 2))
        # Drawing bounding box for every detection
        cv2.rectangle(roi_frame, (xmin, ymin), (xmax, ymax), (0, 0, 255), 2)

        # Updating the tracking for each object
        centers_old, id_obj, is_new, lastKey = update_tracking(centers_old,␣
↪(center_x, center_y), thr_centers, lastKey, i, frame_max)

        # Drawing additional tracking info (like circles) if needed (New)
        for center_x,center_y in centers_old[id_obj].values():
            cv2.circle(roi_frame, (center_x,center_y), 5,(0,255,0),-1)  # Using␣
↪a different color for clarity

        #Updating people in ROI
        count_p+=is_new

        #Drawing above the bounding-box the name of class recognized.
        cv2.putText(img=roi_frame,
            text=id_obj + ':' + str(np.round(confidences[ix], 2)),
            org=(xmin, ymin - 40),  # Adjust this value to position the text␣
↪higher
            fontFace=cv2.FONT_HERSHEY_TRIPLEX,
            fontScale=0.9,
            color=(0, 0, 255),
            thickness=1)


    count_str = f'No. of People in ROI: {count_p}'
    baseline = cv2.getTextSize(count_str, cv2.FONT_HERSHEY_SIMPLEX, font_size,␣
↪font_thickness)[1]
    text_x = int(frame.shape[1] * 0.05)
    text_y = int(frame.shape[0] * 0.1) + baseline

    cv2.putText(img=frame, text=count_str,
                org=(text_x,text_y), fontFace=cv2.FONT_HERSHEY_SIMPLEX,
                fontScale=font_size, color=(255, 255, 255),␣
↪thickness=font_thickness)


    # Append results for this frame to DataFrame (Excel)
    results_df = results_df.append({'Frame': i, 'Timestamp': time_str,␣
↪'People_Count': count_p, 'ID': lastKey}, ignore_index=True)
```

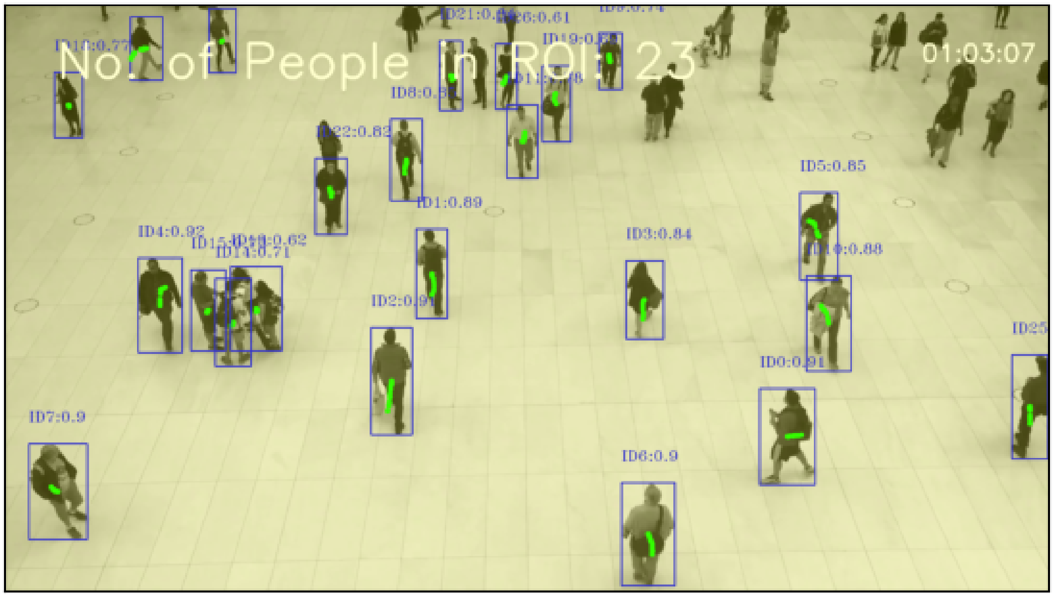
```
    # Filtering tracks history
    centers_old = filter_tracks(centers_old, patience)

    #Drawing the ROI area
    overlay = frame.copy() # make a copy of the original frame

    cv2.polylines(overlay, pts = area_roi, isClosed = True, color=(255, 0,␣
  ↪0),thickness=2)
    cv2.fillPoly(overlay, pts = area_roi, color = (255,255,0))
    frame = cv2.addWeighted(overlay, alpha,frame , 1 - alpha, 0)

    #Saving frames in a list
    frames_list.append(frame)
    #saving transformed frames in a output video formaat
    output_video.write(frame)

# After processing all frames, export the DataFrame to Excel
results_df.to_excel('/content/people_count.xlsx', index=False)

#Releasing the video
output_video.release()
```

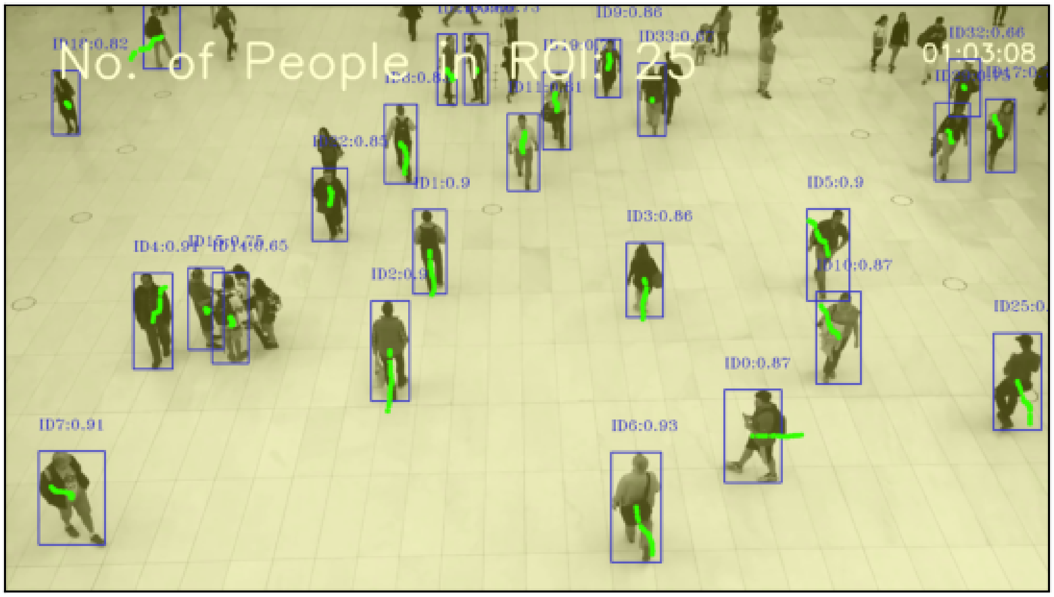
```
  0%|          | 0/341 [00:00<?, ?it/s]
```

```
[ ]: #@title 5.1: Process Video and Audio
     # Check for Existing Output File and Remove if Present
     if os.path.exists(output_video_path):
         os.remove(output_video_path)
     # Process video and audio file
     subprocess.run(
         ["ffmpeg",  "-i",␣
       ↪tmp_output_path,"-crf","18","-preset","veryfast","-hide_banner","-loglevel","error","-vcode
     os.remove(tmp_output_path)
```

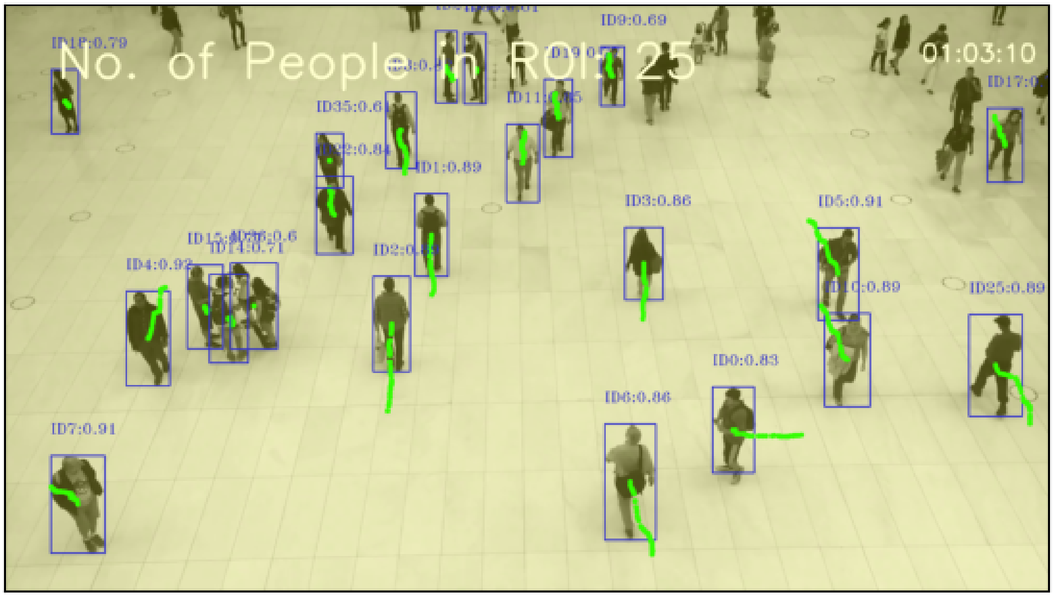
```
[ ]: #@title 5.2: Display of people and results _ Testing
     frames_to_display = 24

     for i in range(frames_to_display):
         frame = frames_list[i*10].copy()

         plt.figure(figsize=(7, 5))
         plt_pretty_image(frame, f'frame {i*20}')
         plt.show()
```


frame 0

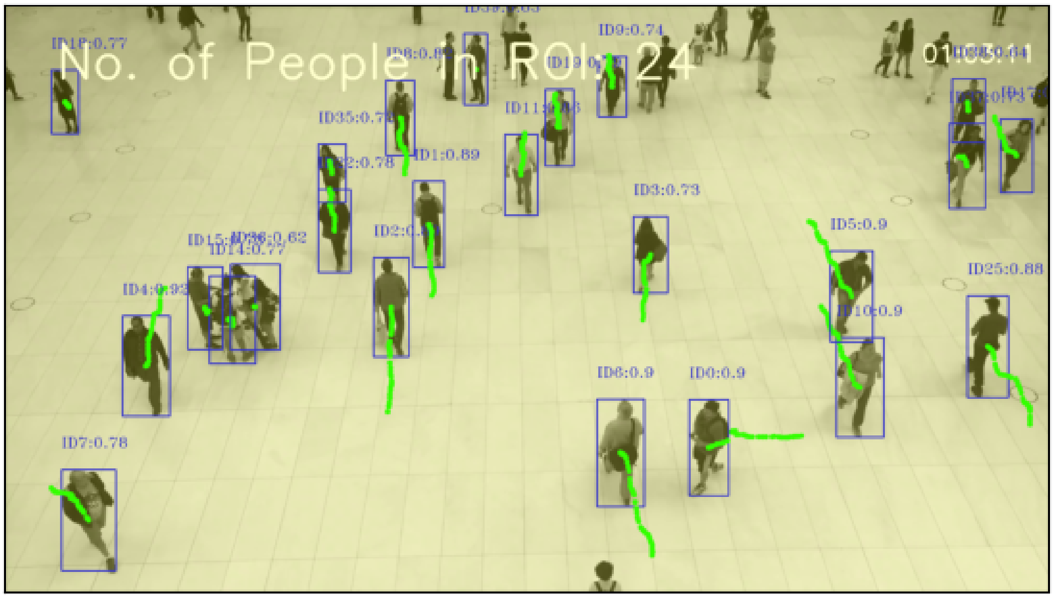

frame 20



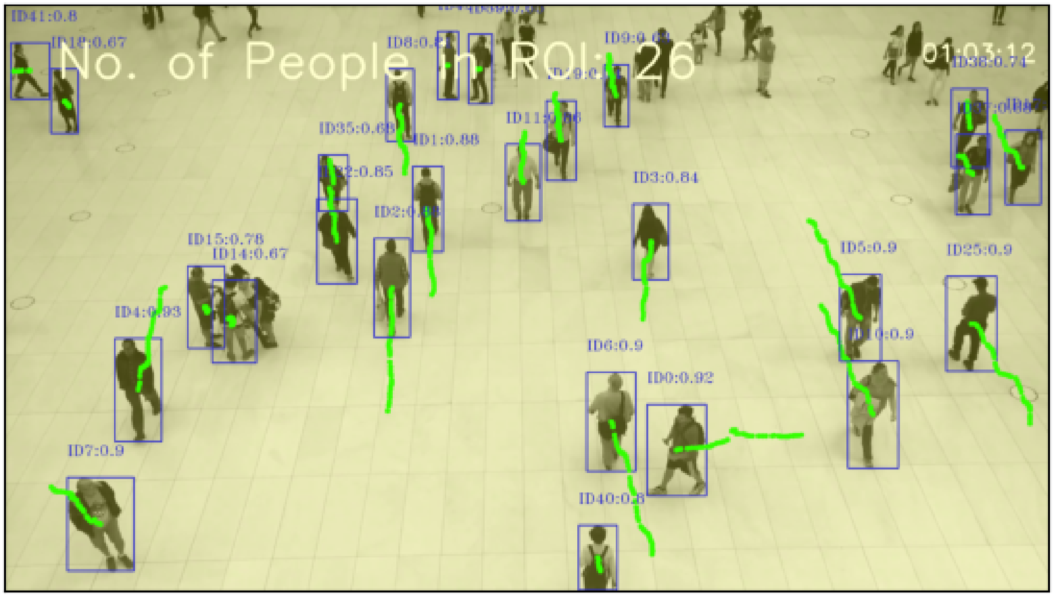
frame 40



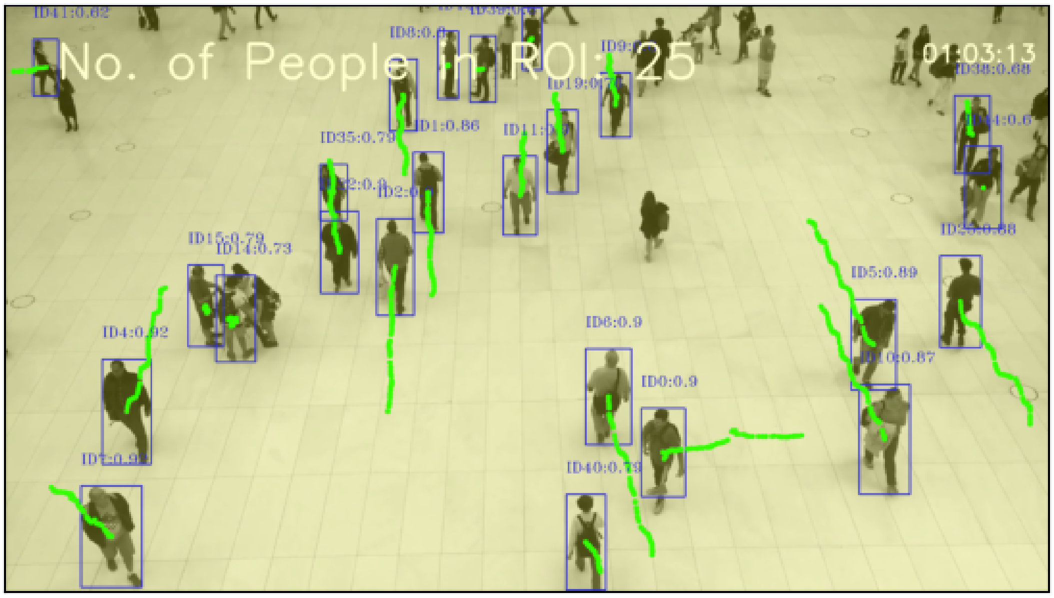
frame 60



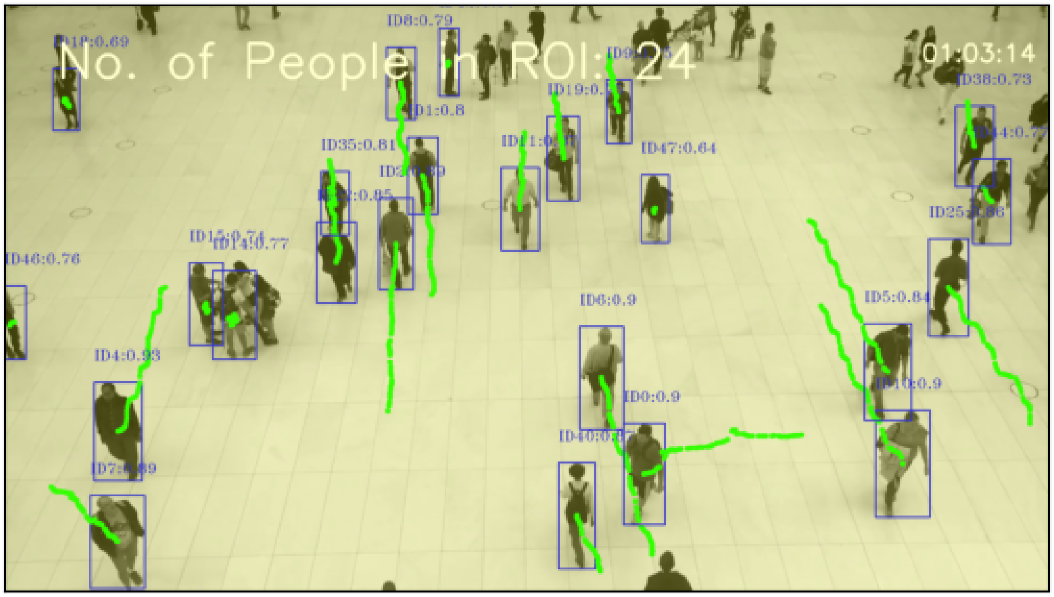
frame 80



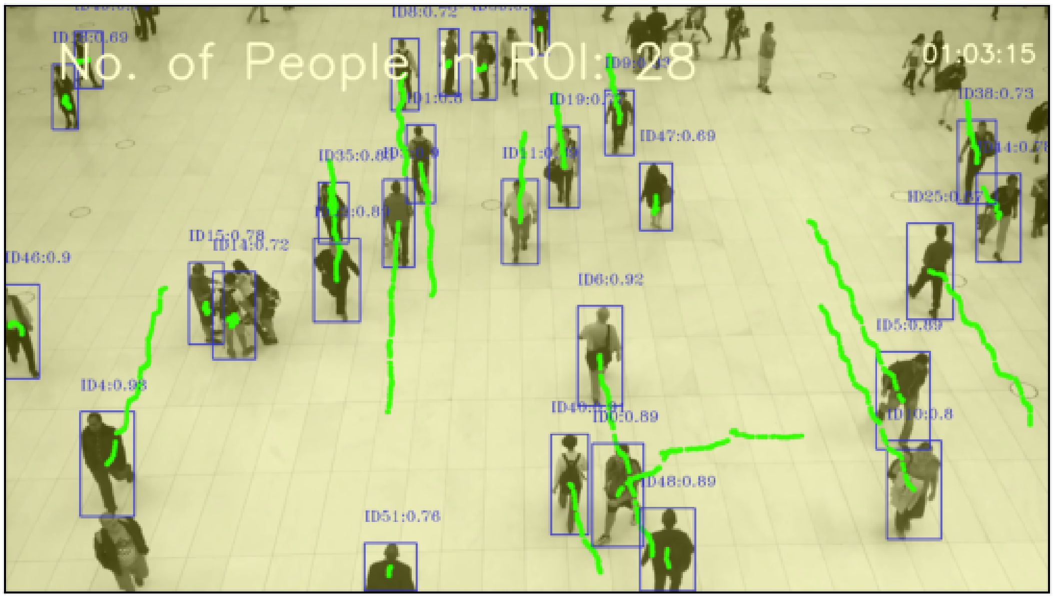
frame 100



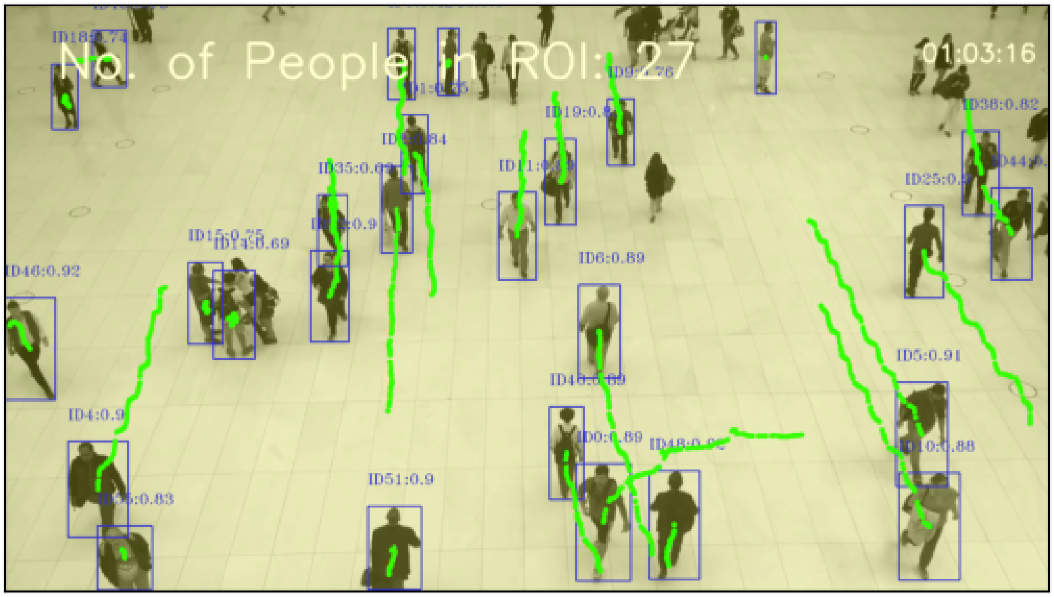
frame 120



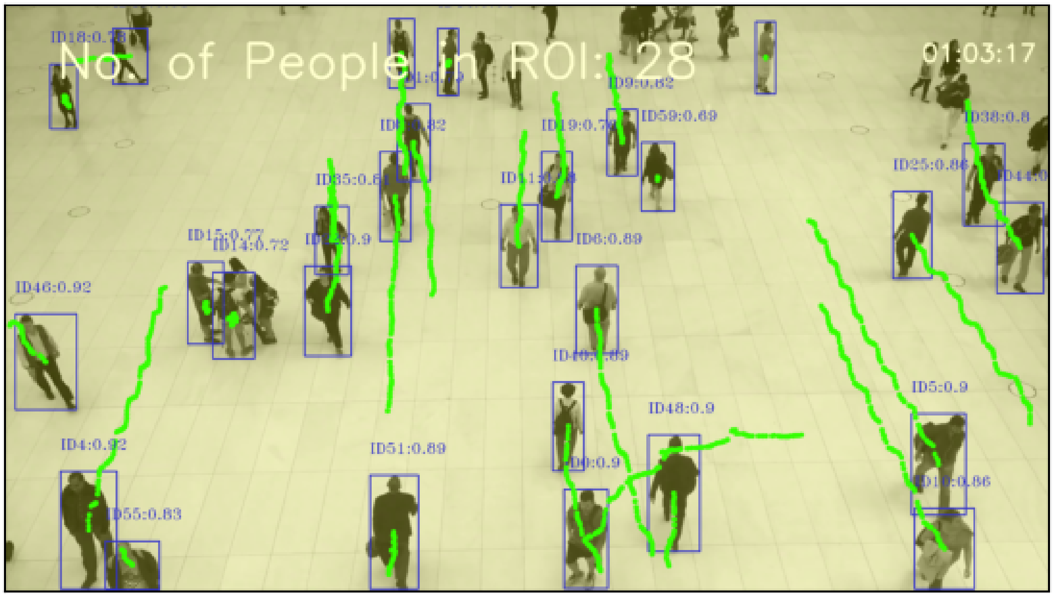
frame 140



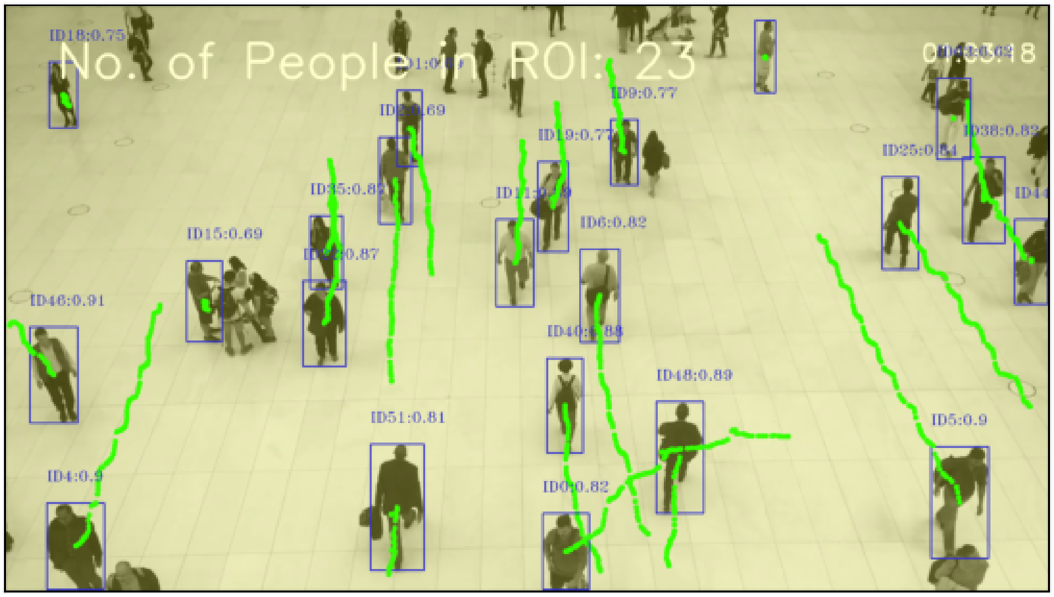
frame 160



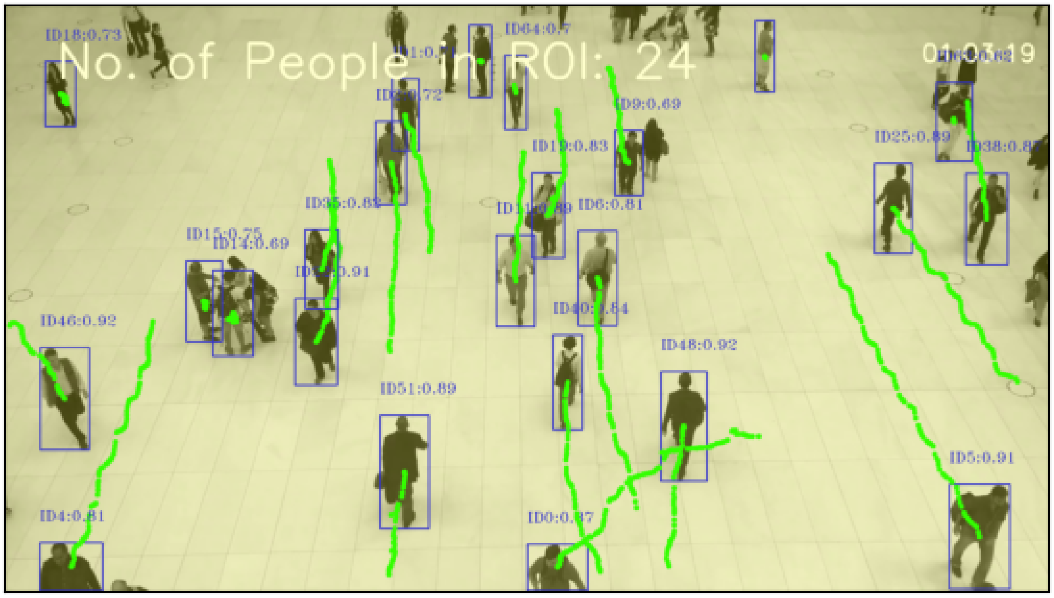
frame 180



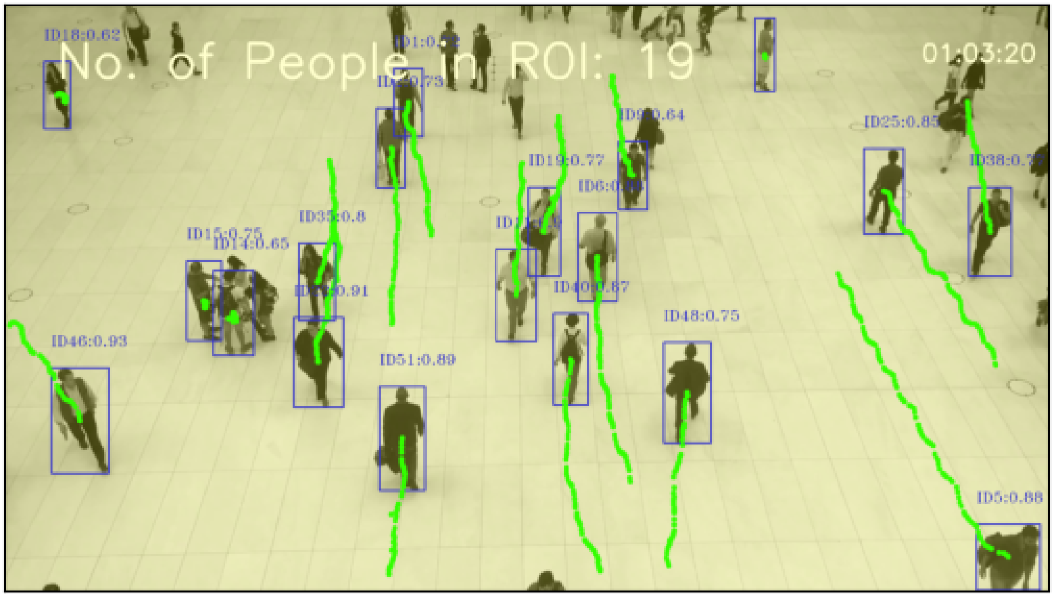
frame 200



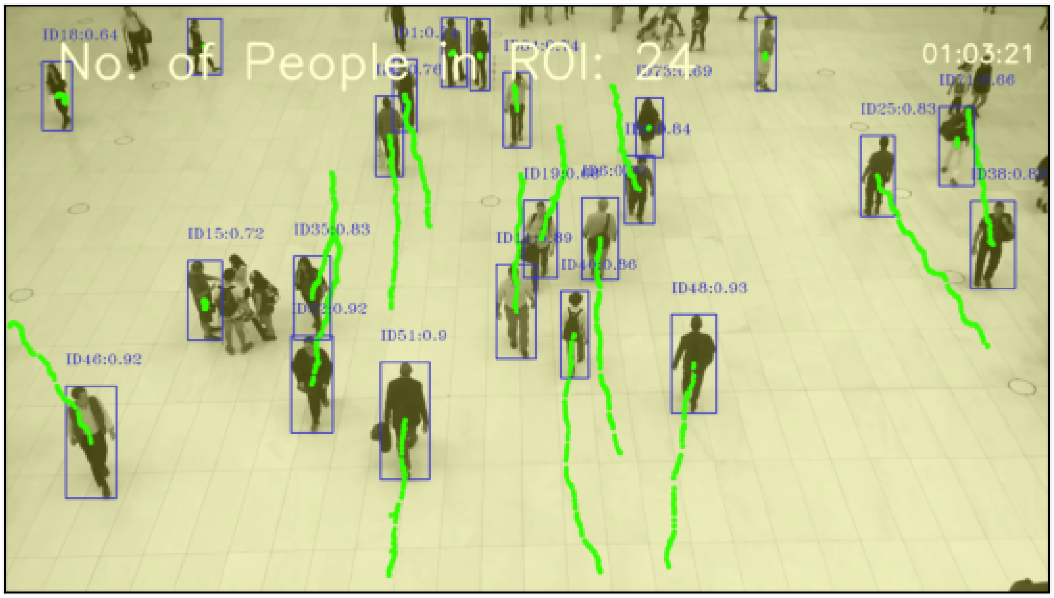
frame 220



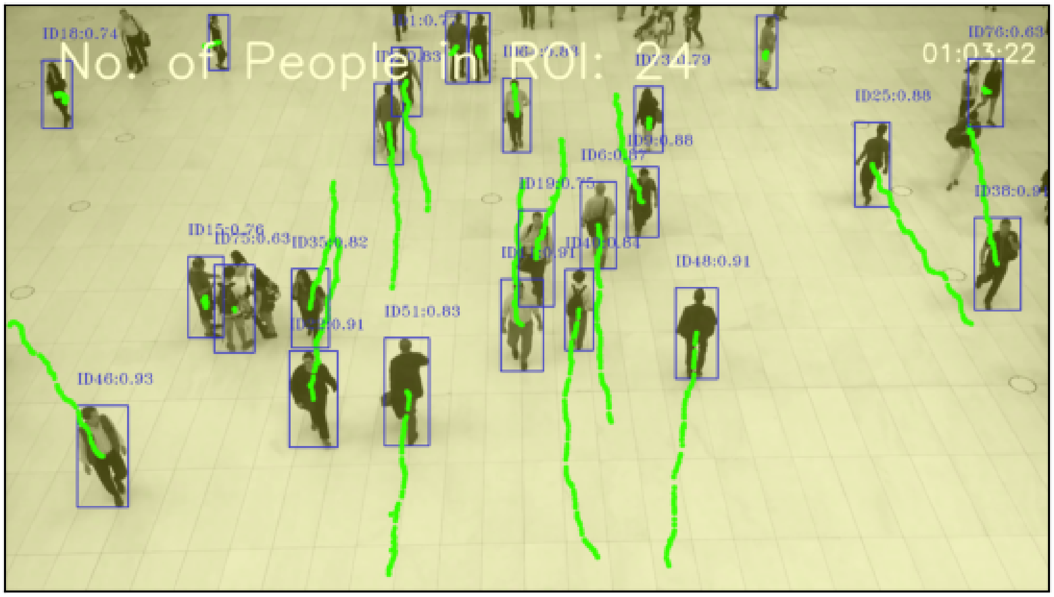
frame 240



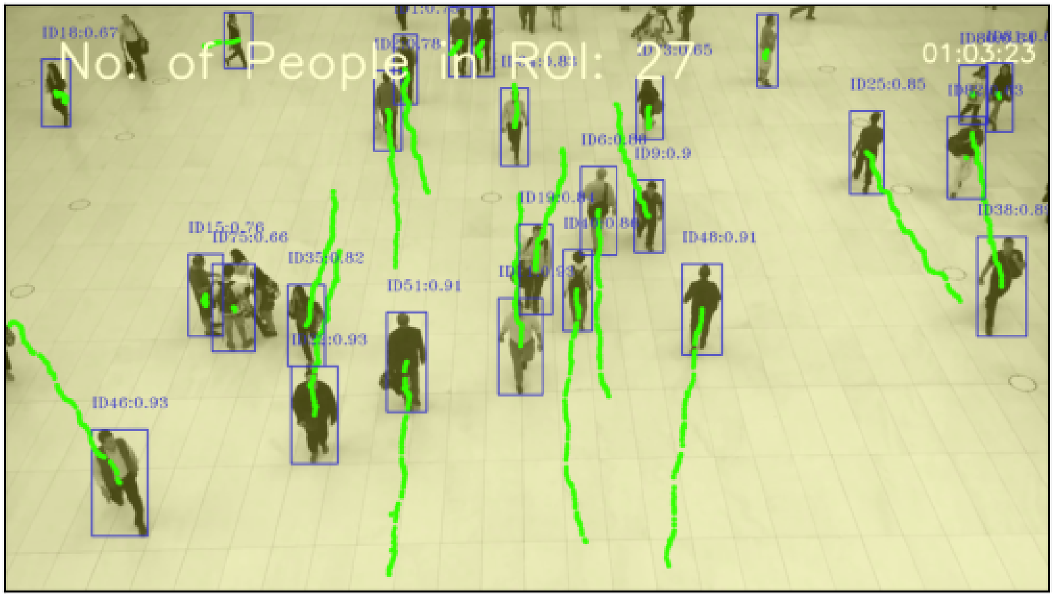
frame 260



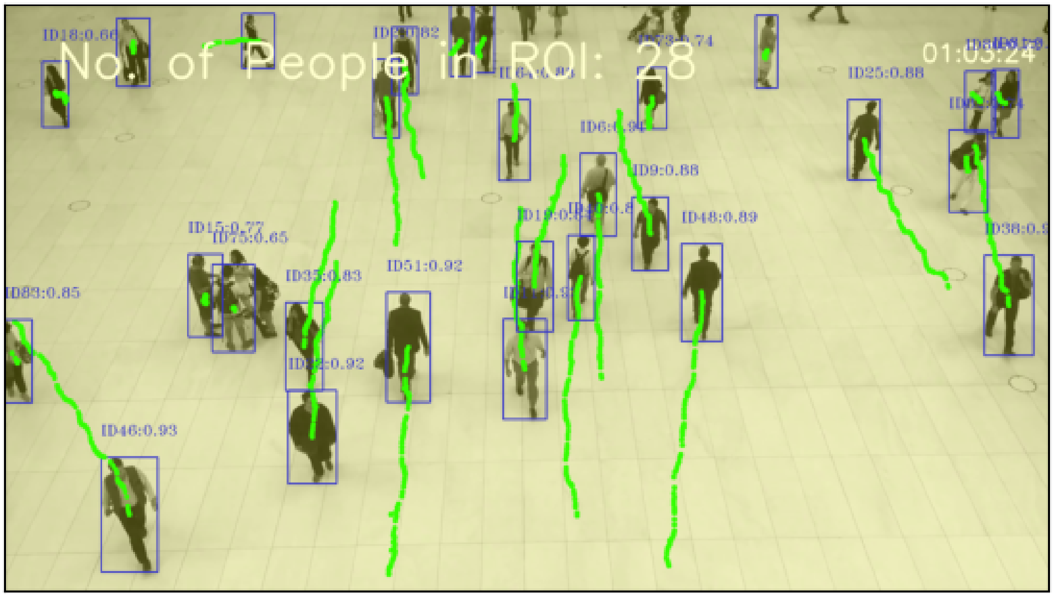
frame 280



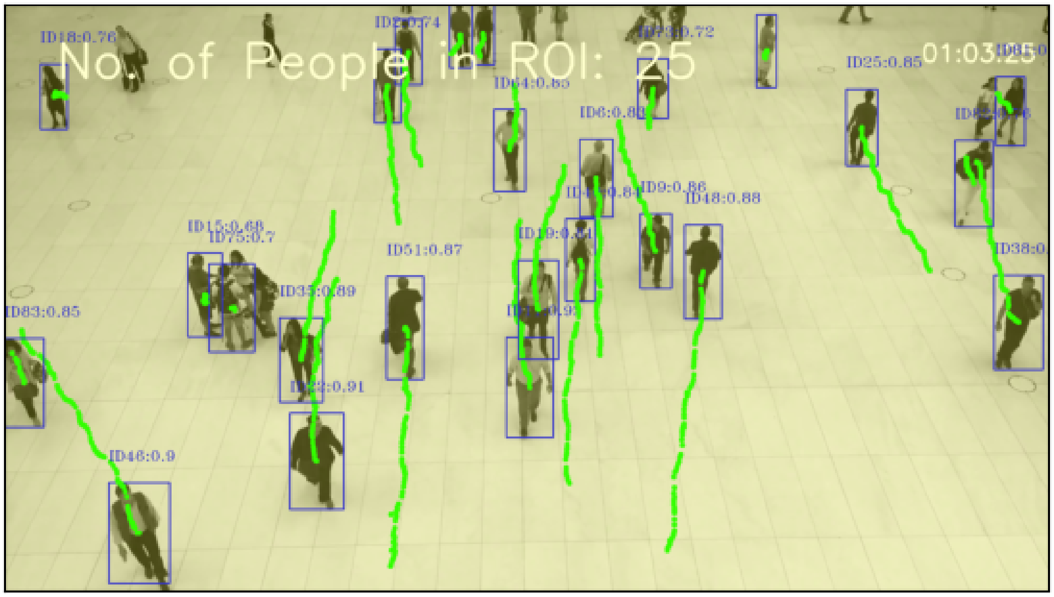
frame 300



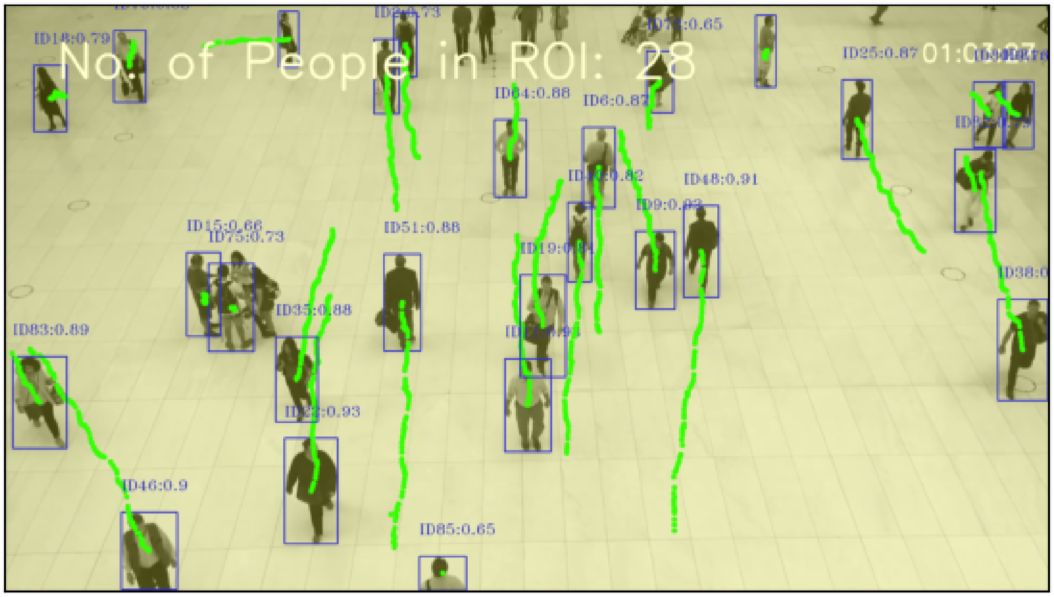
frame 320



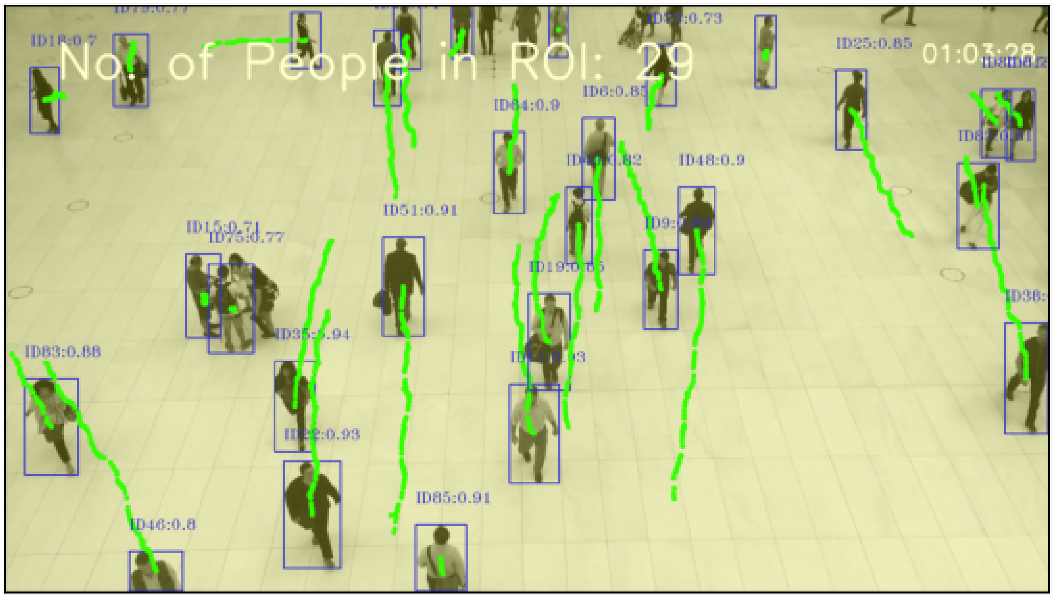
frame 340



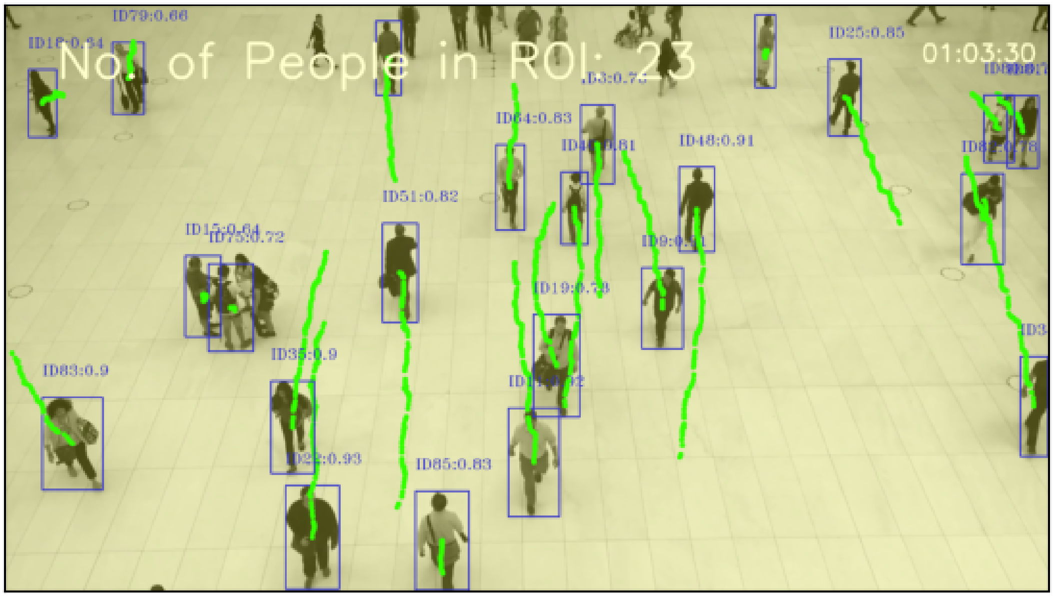
frame 360



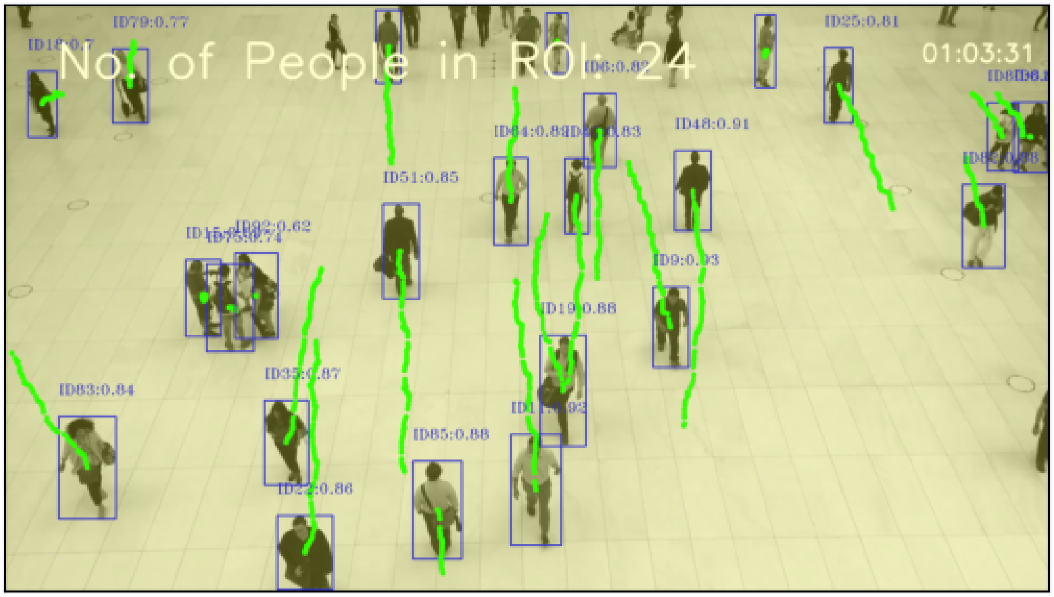
frame 380



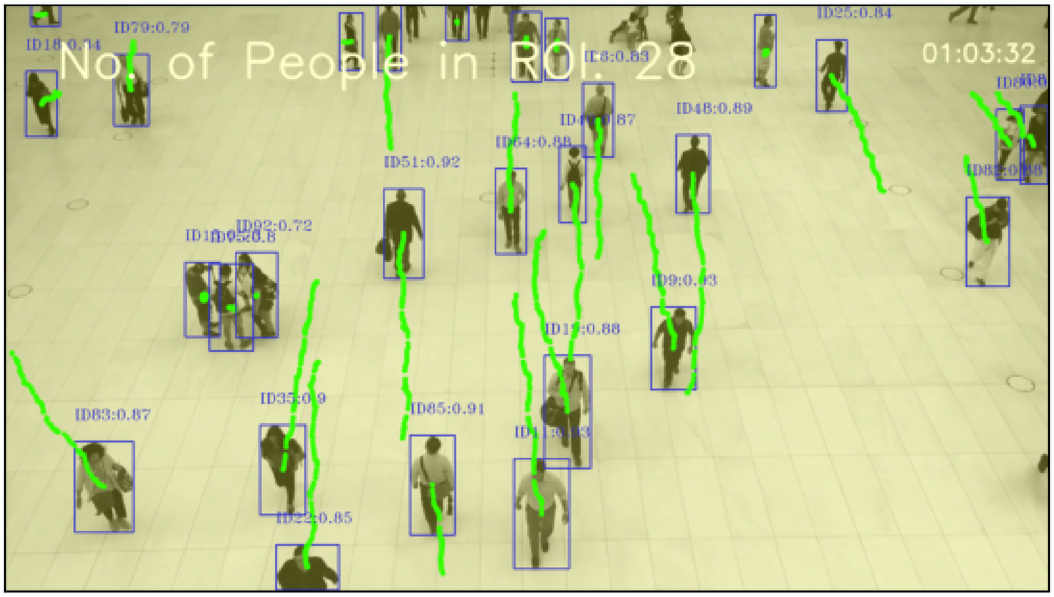
frame 400



frame 420



frame 440



frame 460

```
[ ]: #@title 5.3: Monitoring: Play the processed MP4
     # preview output video
     video_tag = f"""
     <video width={width/2} height={height/2} controls>
```

```
    <source src="data:video/mp4;base64,{video_to_base64(output_video_path)}"␣
  ↪type="video/mp4">
</video>
"""
```

[ ]:
```
HTML(video_tag)
```

[ ]:
```
<IPython.core.display.HTML object>
```

[ ]:
```
#@title 6: Score the test set
# Load the test results file 'count_data.csv'
df = pd.read_excel('/content/drive/MyDrive/AAI-521/Final/Test/
  ↪Score-ManualCount-t6.xlsx')

# Initialize counters
TP = 0
FP = 0
FN = 0

# Calculate TP, FP, and FN
for index, row in df.iterrows():
    system_count = row['System Count']
    manual_count = row['M. Counted']

    TP += min(system_count, manual_count)
    FP += max(0, system_count - manual_count)
    FN += max(0, manual_count - system_count)

# Calculate Precision, Recall, and F1 Score
precision = TP / (TP + FP) if TP + FP > 0 else 0
recall = TP / (TP + FN) if TP + FN > 0 else 0
f1_score = 2 * (precision * recall) / (precision + recall) if precision +␣
  ↪recall > 0 else 0
#Print out the values
print("SCORE VALUES")
print(f"Precision: {precision:.4f}")
print(f"Recall: {recall:.4f}")
print(f"F1 Score: {f1_score:.4f}")
```

```
SCORE VALUES
Precision: 0.9948
Recall: 0.7265
F1 Score: 0.8397
```

#This section is for emulating a real-time Camera sensor in the IoT

[ ]:
```
#@title 7: Installing required packages and testing the model
# import dependencies
from IPython.display import display, Javascript, Image
from google.colab.output import eval_js
from google.colab.patches import cv2_imshow
from base64 import b64decode, b64encode
import cv2
import numpy as np
import PIL
import io
import html
import time
import matplotlib.pyplot as plt
%matplotlib inline
```

[ ]:
```
#@title 7.1: Open real-time camera capture with YOLO Object Detection
# Load the YOLOv8 model
model = YOLO("yolov8n.pt")  # Adjust the model path as necessary
dict_classes = model.model.names  # Class names

# Initialize camera stream
cap = cv2.VideoCapture(0)  # Use appropriate index or URL for your camera

try:
    while True:
        # Read frame from camera
        ret, frame = cap.read()
        if not ret:
            print("Error: failed to capture image")
            break

        # Perform detection
        results = model.predict(frame)

        # Draw bounding boxes and labels
        for detection in results.xyxy[0]:
            # Extract data
            xmin, ymin, xmax, ymax, conf, cls = detection
            label = dict_classes[int(cls)]

            # Draw bounding box
            cv2.rectangle(frame, (int(xmin), int(ymin)), (int(xmax),␣
 ↪int(ymax)), (0, 255, 0), 2)
            # Draw label
            cv2.putText(frame, f"{label} {conf:.2f}", (int(xmin), int(ymin)-10),
                        cv2.FONT_HERSHEY_SIMPLEX, 0.5, (0, 255, 0), 2)
        # Display the frame
        cv2.imshow("Camera Feed", frame)

        # Break loop on specific key press, e.g., 'q'
        if cv2.waitKey(1) & 0xFF == ord('q'):
            break
finally:
    cap.release()
    cv2.destroyAllWindows()
```