

SpotOn

Progress #3

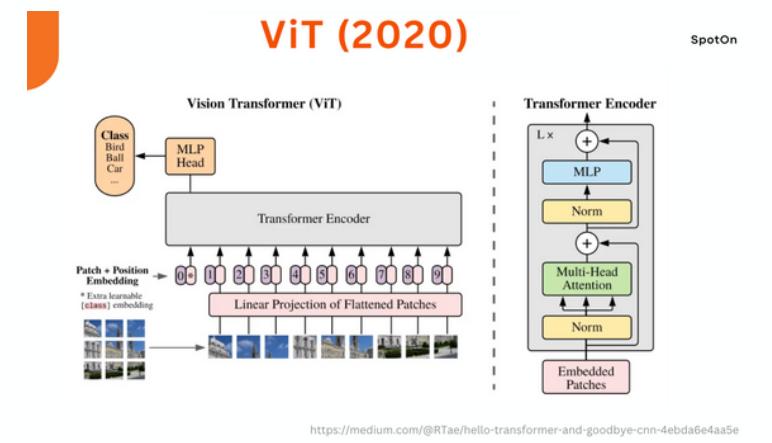
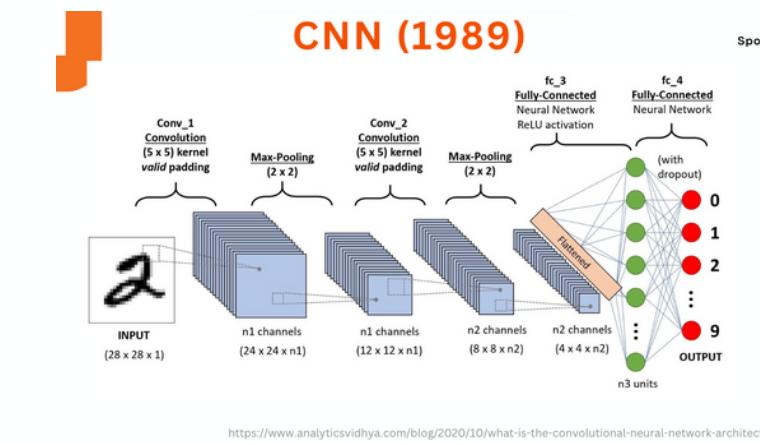


Agenda

- Recap
- ML Deployment
- Updated Architecture
- How detection and tracking work together
 - Problem
 - Solution
- Unified Spatial Mapping
- Data Flow

Recap

CNN & ViT



Re-Identification



Camera View Selection



ML Deployment

**Embedded model in
the backend**

**Separate ML Service
(ML Flow)**

Deployment Comparing

Comparison Table:

Feature	Embedded Model (in Backend)	Separate ML Server (MLflow via HTTPS)
Added Latency/Cycle	~0 ms (only inference time matters)	~100 ms - 300 ms+ (just for communication)
Potential Max FPS	Limited primarily by slowest inference step	Severely limited by communication overhead
Example @ 5 FPS	Budget: 200ms/frame. If inference < 200ms, OK.	Budget: 200ms/frame. Communication alone (100-300ms+) likely exceeds budget, leaving no time for inference.
Example @ 2 FPS	Budget: 500ms/frame. Inference likely fits. OK.	Budget: 500ms/frame. Communication (100-300ms+) consumes 20-60%+ of budget. Might be possible if inference is fast.
Scalability	Backend+Model scale together	Independent ML scaling (Good)
Maintainability	Tighter coupling	Better separation (Good)
Resource Needs	Backend needs CPU + GPU	Backend (CPU), ML Server (CPU+GPU)

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Deployment Comparing

Cost Analysis for Deployment Scenarios

Scenario 1: Minimal Backend Load

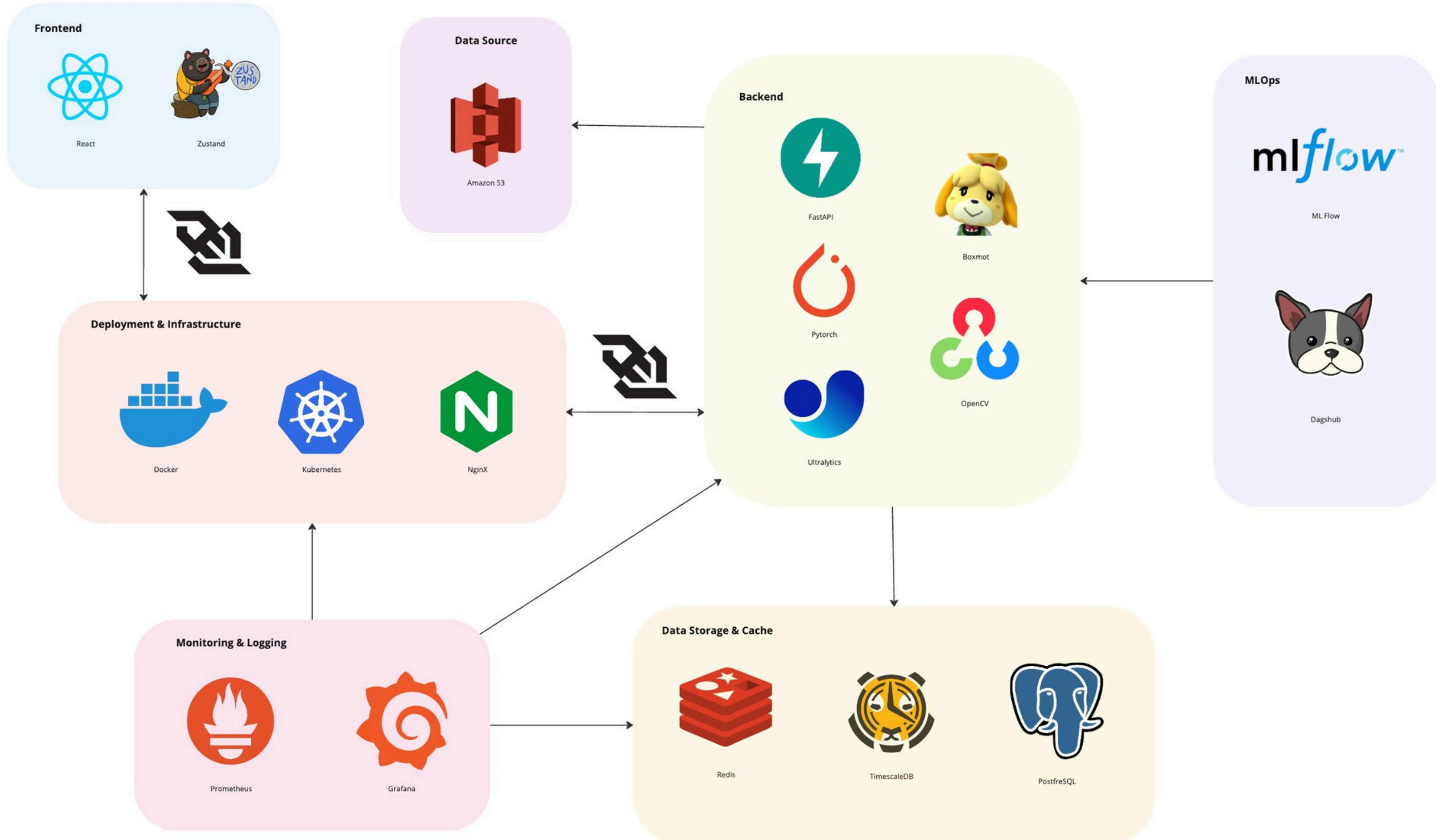
- **Option A (Embedded)**: Single g4dn.xlarge hosting both backend and ML
 - Cost: \$384/month
- **Option B (Dedicated Servers)**: Separate t3.large (backend) and g4dn.xlarge (ML)
 - Cost: \$445/month
- **Conclusion**: Embedded approach saves ~\$61/month (14% cheaper)

Scenario 2: Significant Backend Load

- **Option A (Embedded)**: Requires larger g4dn.2xlarge for combined workload
 - Cost: \$549/month
- **Option B (Dedicated Servers)**: Same as above, no change needed
 - Cost: \$445/month
- **Conclusion**: Dedicated servers save ~\$104/month (19% cheaper)

~RTX 4060

Updated Architecture



How detection and tracking work together

Problem #1: Barely detect the people

Problem #1



1 RTDETR instance, 1 Cam

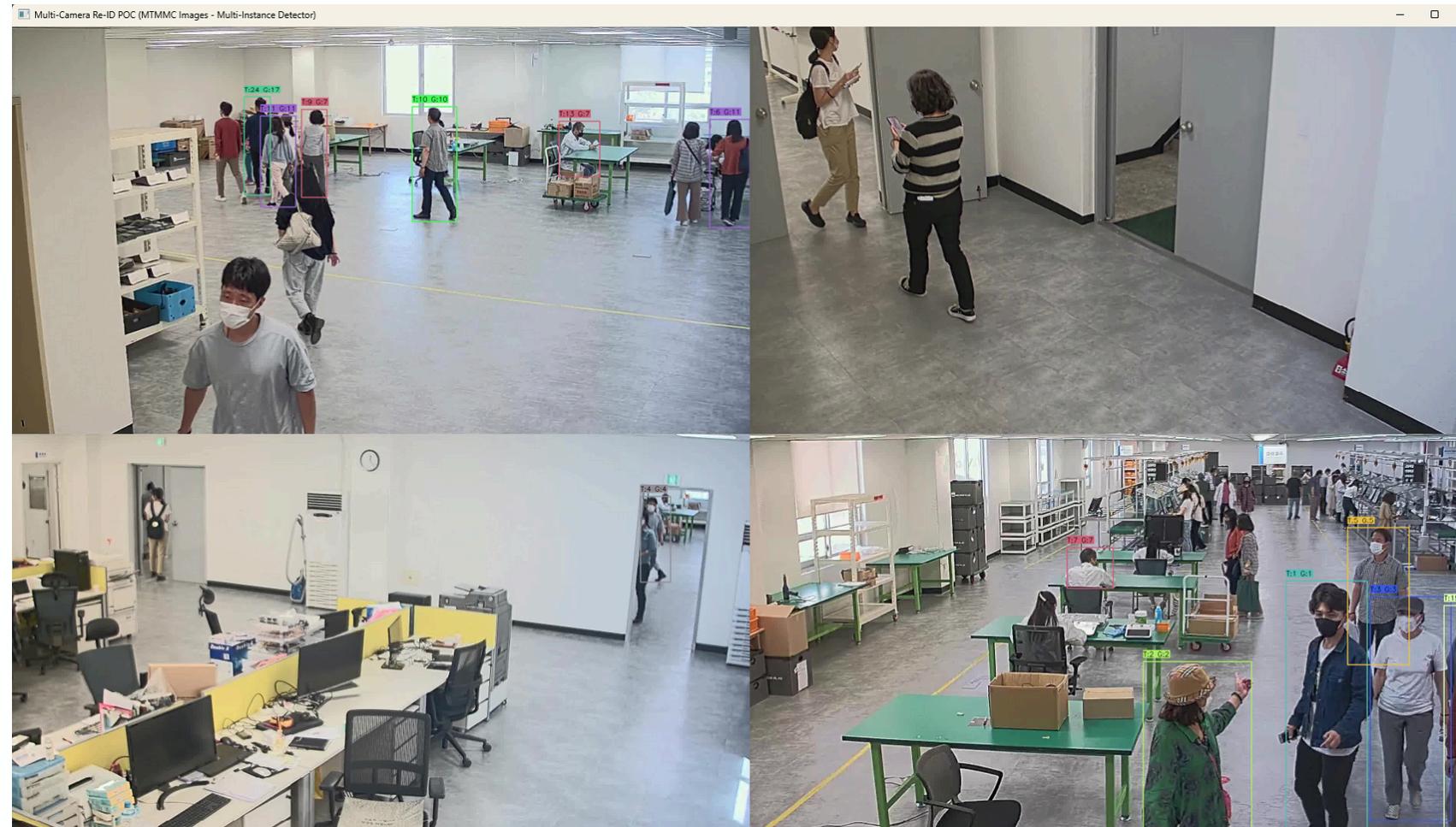
Problem #1



4 RTDETR instances (Trackers)

Problem #1

Yolo 4 cams

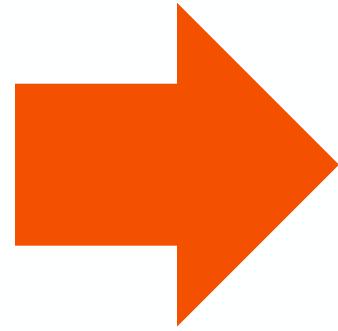


Yolo 2 cams



Problem #1

Why not Faster R CNN?



It doesn't have a built-in tracker.

Investigate Problem #1

Single Instance

```
[F:28] Potential ID Switch: T:13 (was G:13) -> G:7 (S:0.656)

--- Frame 30 (000030.jpg) ---
Timings (ms): Total=266.2 | Detect/Track=209.1 | StateUpdate=1.0 | FeatExtract=54.1 | ReID=2.0
[F:34] Potential ID Switch: T:10 (was G:10) -> G:20 (S:0.773)

--- Frame 40 (000040.jpg) ---
Timings (ms): Total=203.6 | Detect/Track=203.6 | StateUpdate=0.0 | FeatExtract=0.0 | ReID=0.0
[F:45] Potential ID Switch: T:26 (was G:19) -> G:2 (S:0.811)

--- Frame 50 (000050.jpg) ---
Timings (ms): Total=235.5 | Detect/Track=235.5 | StateUpdate=0.0 | FeatExtract=0.0 | ReID=0.0
[F:55] Potential ID Switch: T:19 (was G:17) -> G:10 (S:0.686)
[F:56] Potential ID Switch: T:10 (was G:20) -> G:10 (S:0.855)
[F:59] Potential ID Switch: T:51 (was G:23) -> G:15 (S:0.694)
[F:60] Potential ID Switch: T:53 (was G:22) -> G:16 (S:0.698)

--- Frame 60 (000060.jpg) ---
Timings (ms): Total=239.4 | Detect/Track=214.0 | StateUpdate=1.0 | FeatExtract=22.4 | ReID=2.0
[F:65] Potential ID Switch: T:56 (was G:28) -> G:20 (S:0.667)
[F:67] Potential ID Switch: T:56 (was G:20) -> G:28 (S:0.656)
```

Four Instances

```
[F:27] Potential ID Switch: T:11 (was G:11) -> G:8 (S:0.762)
[F:30] Potential ID Switch: T:13 (was G:13) -> G:8 (S:0.769)

--- Frame 30 (000030.jpg) ---
Timings (ms): Total=81.1 | Detect/Track=52.4 | StateUpdate=0.0 | FeatExtract=27.7 | ReID=1.0
[F:38] Potential ID Switch: T:11 (was G:8) -> G:5 (S:0.719)

--- Frame 40 (000040.jpg) ---
Timings (ms): Total=55.6 | Detect/Track=55.6 | StateUpdate=0.0 | FeatExtract=0.0 | ReID=0.0

--- Frame 50 (000050.jpg) ---
Timings (ms): Total=54.2 | Detect/Track=54.2 | StateUpdate=0.0 | FeatExtract=0.0 | ReID=0.0

--- Frame 60 (000060.jpg) ---
Timings (ms): Total=52.1 | Detect/Track=52.1 | StateUpdate=0.0 | FeatExtract=0.0 | ReID=0.0
[F:65] Potential ID Switch: T:29 (was G:18) -> G:10 (S:0.697)

--- Frame 70 (000070.jpg) ---
Timings (ms): Total=54.4 | Detect/Track=53.4 | StateUpdate=1.0 | FeatExtract=0.0 | ReID=0.0
[F:74] Potential ID Switch: T:25 (was G:17) -> G:10 (S:0.748)
```

Investigate Problem #1

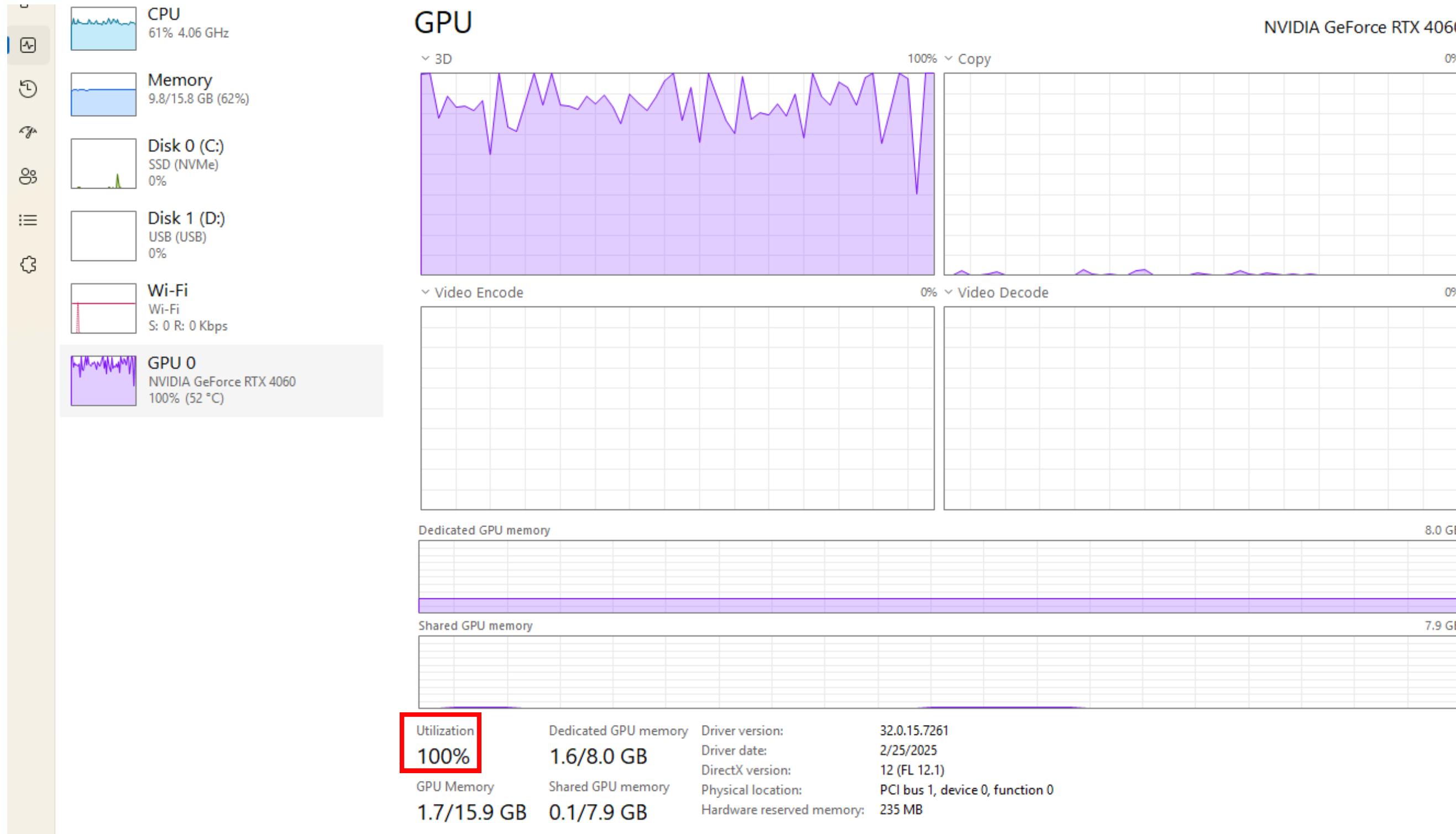
Single Instance

- **Detect/Track:** ~55ms
- **FeatExtract:** ~20-60ms
- **ReID:** ~1ms

Four Instances

- **Detect/Track:** ~225ms
- **FeatExtract:** ~8-65ms
- **ReID:** ~16ms

Investigate Problem #1



Hit a hardware resource bottleneck

Solution #1

Strategies

- Modify the ByteTrack
- Batch Processing
- Use Half Precision
- Reduce Input Resolution
- Compile the model into faster format (ONNX/TensorRT)
- Detection frame skipping
- Switch to faster detection model

Solution #1

Strategies

- Modify the ByteTrack
- Batch Processing
- Use Half Precision
- Reduce Input Resolution
- Compile the model into faster format (ONNX/TensorRT)
- Detection frame skipping
- Switch to faster detection model



Effective



Untested



Unsuccessful

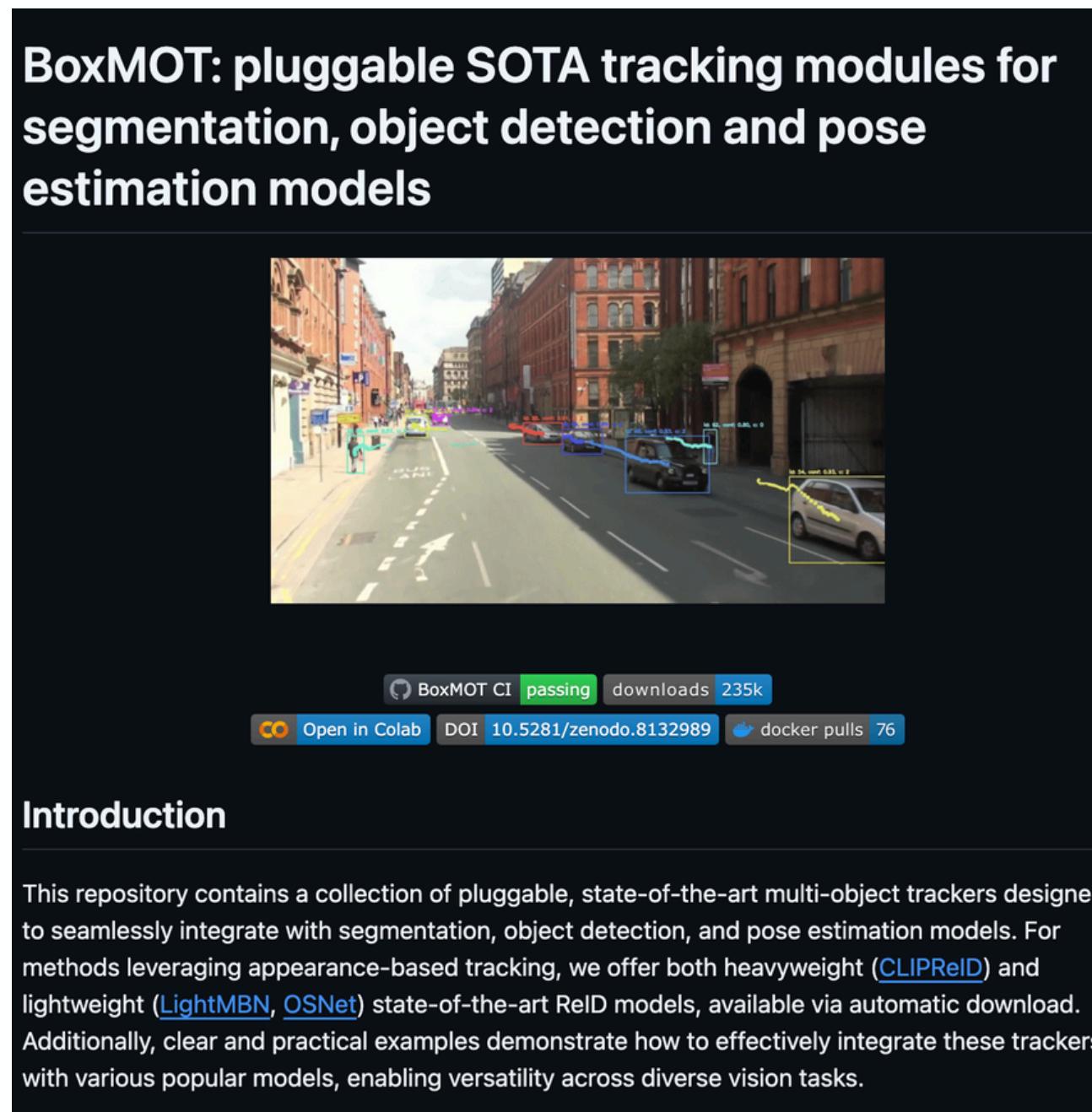
Solution #1 (Modify the ByteTrack)

We need to reduce the tracker instances from $4 \rightarrow 1$

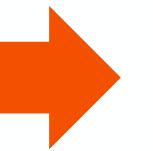


Writing our own bytetrack with custom logic

Solution #1 (Modify the ByteTrack)



Forked



Files

master + Q

Go to file t

- boxmot
 - configs
 - data
 - motion
 - postprocessing
 - trackers
 - utils
 - __init__.py
 - tracker_zoo.py
- README.md

boxmot / boxmot / CoJwizzed feat: remove everything except bytetrack

This branch is 2 commits ahead of, 3 commits behind mikel-brostrom/boxmot:master .

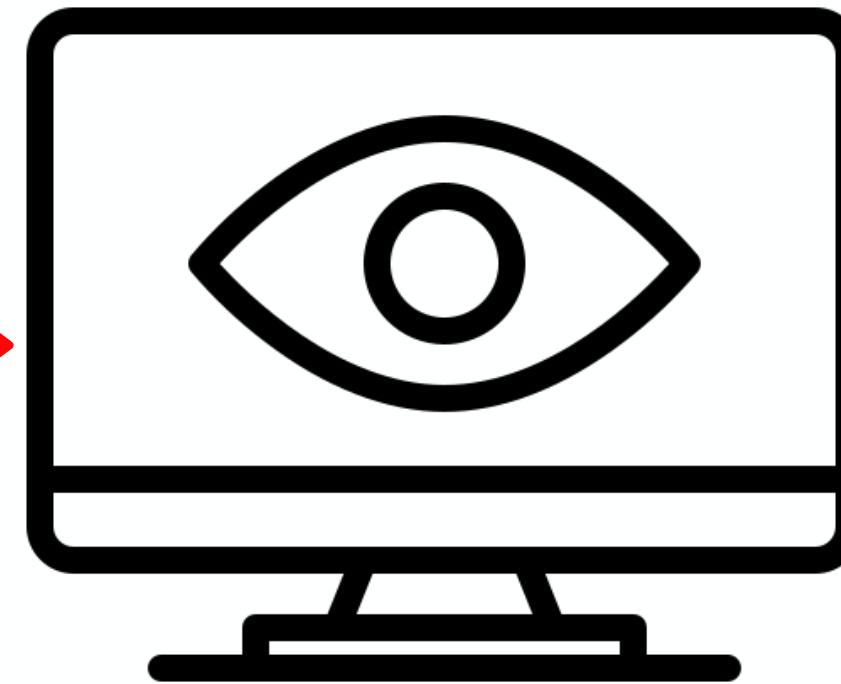
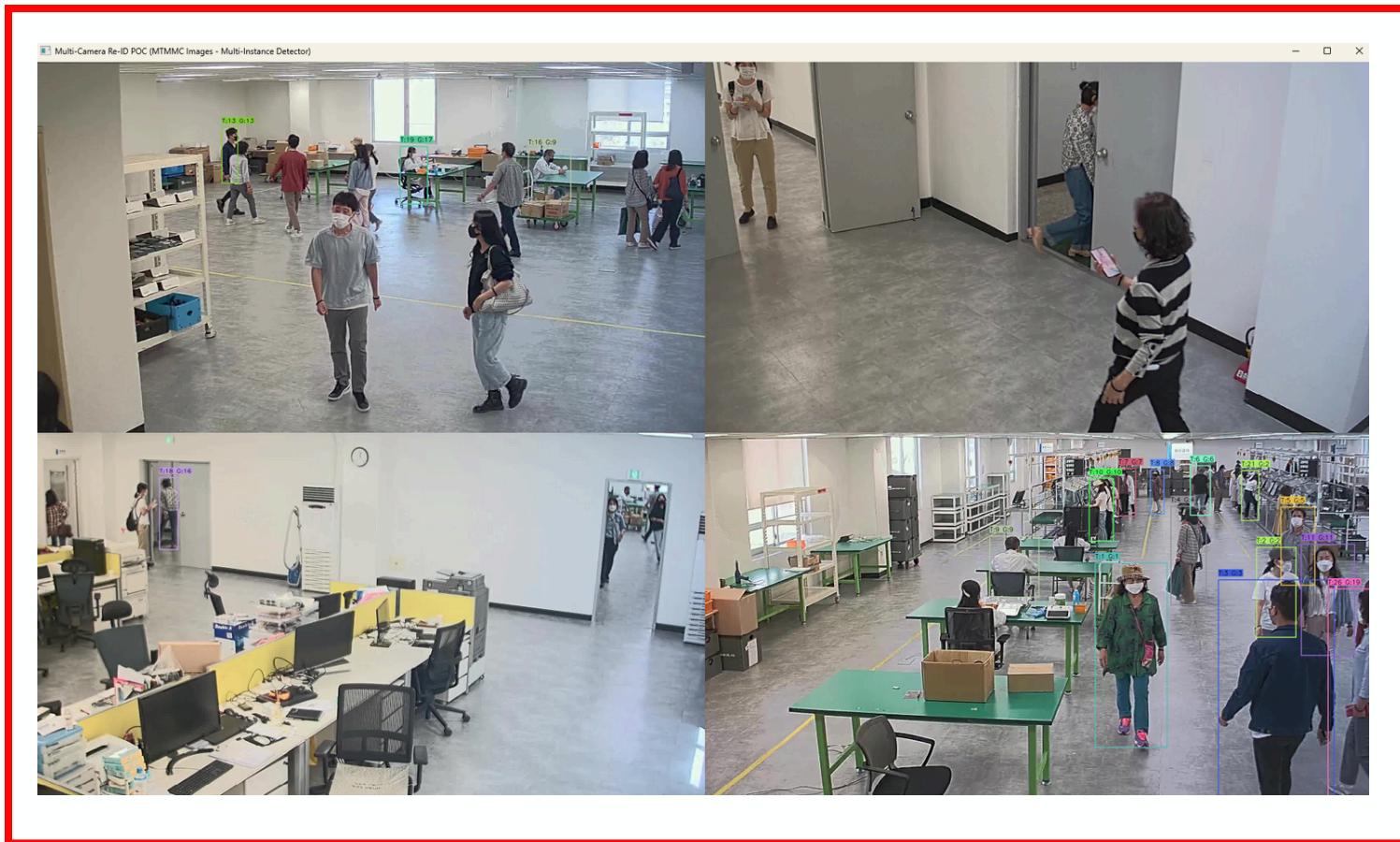
Contribute Sync fork

Name	Last commit message
...	feat: remove everything except bytetrack
configs	fix import
data	feat: remove everything except bytetrack
motion	optimized exec speed
postprocessing	feat: remove everything except bytetrack
trackers	only print on main thread
utils	Bumping version from 12.0.5 to 12.0.6
__init__.py	Added boosttrack
tracker_zoo.py	

Solution #1 (Batch Processing)

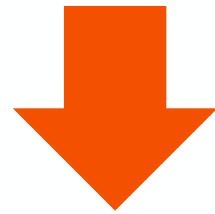


Solution #1 (Batch Processing)



Solution #1 (Use Half Precision)

FP32 (Single Precision): This is the standard, default floating-point format used in deep learning. It uses **32 bits** to represent a number, offering a good balance of range (how large or small the numbers can be) and precision (how accurately numbers can be represented).



FP16 (Half Precision): This format uses only **16 bits**. Compared to FP32, it has a smaller range and lower precision.

Solution #1 (Reduce Input Resolution)

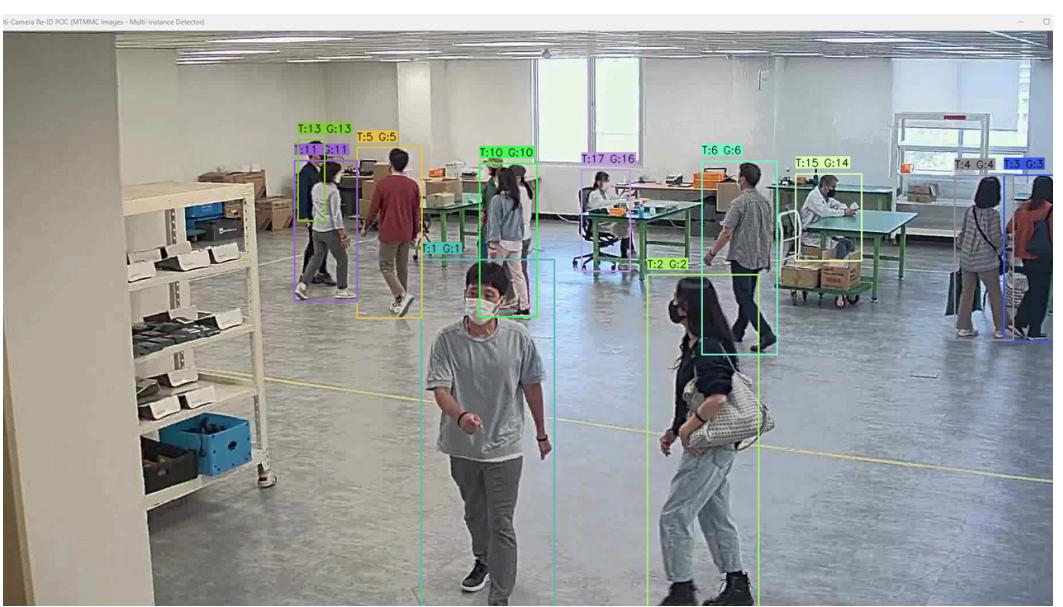
Default



~1.97 fps

```
-04-13 15:41:25 [INFO] --- Starting Frame Processing Loop ---
-04-13 15:41:26 [INFO] Frame 0 | Time: 925.5ms | AvgFPS: 1.08 | Pipeline: detection_tracking=579.9 | feature_ext=200.1 | reid=1.1 | total=881.0 | Tracks: 43
-04-13 15:41:26 [INFO] Frame 1 | Time: 415.0ms | AvgFPS: 1.47 | Pipeline: detection_tracking=379.1 | feature_ext=0.0 | reid=0.0 | total=379.1 | Tracks: 41
-04-13 15:41:27 [INFO] Frame 2 | Time: 480.0ms | AvgFPS: 1.62 | Pipeline: detection_tracking=378.1 | feature_ext=65.1 | reid=2.0 | total=445.2 | Tracks: 42
-04-13 15:41:27 [INFO] Frame 3 | Time: 460.5ms | AvgFPS: 1.71 | Pipeline: detection_tracking=375.6 | feature_ext=40.1 | reid=5.0 | total=420.7 | Tracks: 44
-04-13 15:41:28 [INFO] Frame 4 | Time: 500.0ms | AvgFPS: 1.75 | Pipeline: detection_tracking=387.2 | feature_ext=68.0 | reid=0.1 | total=401.9 | Tracks: 45
-04-13 15:41:35 [INFO] Frame 20 | Time: 602.1ms | AvgFPS: 2.01 | Pipeline: detection_tracking=388.7 | feature_ext=140.1 | reid=51.4 | total=560.2 | Tracks: 38
-04-13 15:41:45 [INFO] Frame 40 | Time: 639.8ms | AvgFPS: 2.06 | Pipeline: detection_tracking=382.4 | feature_ext=107.7 | reid=51.6 | total=601.8 | Tracks: 37
-04-13 15:41:54 [INFO] Frame 60 | Time: 578.8ms | AvgFPS: 2.07 | Pipeline: detection_tracking=381.3 | feature_ext=118.1 | reid=45.0 | total=544.4 | Tracks: 39
-04-13 15:42:04 [INFO] Frame 80 | Time: 515.5ms | AvgFPS: 2.07 | Pipeline: detection_tracking=388.8 | feature_ext=70.1 | reid=41.0 | total=479.9 | Tracks: 38
-04-13 15:42:14 [INFO] Frame 100 | Time: 528.8ms | AvgFPS: 2.07 | Pipeline: detection_tracking=381.9 | feature_ext=71.6 | reid=38.0 | total=491.9 | Tracks: 42
-04-13 15:42:23 [INFO] Frame 120 | Time: 497.0ms | AvgFPS: 2.07 | Pipeline: detection_tracking=367.5 | feature_ext=66.1 | reid=29.0 | total=462.6 | Tracks: 35
-04-13 15:42:33 [INFO] Frame 140 | Time: 619.0ms | AvgFPS: 2.06 | Pipeline: detection_tracking=394.7 | feature_ext=159.1 | reid=29.2 | total=583.1 | Tracks: 36
-04-13 15:42:43 [INFO] Frame 160 | Time: 490.1ms | AvgFPS: 2.08 | Pipeline: detection_tracking=368.5 | feature_ext=63.2 | reid=22.0 | total=453.7 | Tracks: 32
-04-13 15:42:52 [INFO] Frame 180 | Time: 498.0ms | AvgFPS: 2.07 | Pipeline: detection_tracking=388.4 | feature_ext=80.1 | reid=40.0 | total=460.1 | Tracks: 33
-04-13 15:43:02 [INFO] Frame 200 | Time: 503.5ms | AvgFPS: 2.07 | Pipeline: detection_tracking=377.4 | feature_ext=105.3 | reid=24.3 | total=468.0 | Tracks: 30
-04-13 15:43:12 [INFO] Frame 220 | Time: 526.9ms | AvgFPS: 2.07 | Pipeline: detection_tracking=388.8 | feature_ext=85.4 | reid=25.0 | total=491.3 | Tracks: 38
-04-13 15:43:22 [INFO] Frame 240 | Time: 523.9ms | AvgFPS: 2.06 | Pipeline: detection_tracking=397.6 | feature_ext=79.1 | reid=11.0 | total=487.7 | Tracks: 37
-04-13 15:43:32 [INFO] Frame 260 | Time: 505.3ms | AvgFPS: 2.05 | Pipeline: detection_tracking=375.4 | feature_ext=82.1 | reid=9.0 | total=466.5 | Tracks: 41
-04-13 15:43:42 [INFO] Frame 280 | Time: 464.0ms | AvgFPS: 2.05 | Pipeline: detection_tracking=373.2 | feature_ext=65.3 | reid=11.0 | total=429.5 | Tracks: 34
-04-13 15:43:52 [INFO] Frame 300 | Time: 539.8ms | AvgFPS: 2.05 | Pipeline: detection_tracking=399.8 | feature_ext=93.2 | reid=19.2 | total=503.2 | Tracks: 38
-04-13 15:44:02 [INFO] Frame 320 | Time: 484.1ms | AvgFPS: 2.05 | Pipeline: detection_tracking=376.2 | feature_ext=61.4 | reid=11.4 | total=469.0 | Tracks: 34
-04-13 15:44:15 [INFO] Frame 340 | Time: 476.5ms | AvgFPS: 2.08 | Pipeline: detection_tracking=368.9 | feature_ext=21.3 | reid=9.0 | total=399.2 | Tracks: 33
-04-13 15:44:26 [INFO] Frame 360 | Time: 518.3ms | AvgFPS: 1.99 | Pipeline: detection_tracking=376.7 | feature_ext=40.0 | reid=9.0 | total=425.7 | Tracks: 37
-04-13 15:44:37 [INFO] Frame 380 | Time: 545.0ms | AvgFPS: 1.98 | Pipeline: detection_tracking=382.5 | feature_ext=76.9 | reid=5.1 | total=444.5 | Tracks: 35
-04-13 15:44:48 [INFO] Frame 400 | Time: 502.1ms | AvgFPS: 1.98 | Pipeline: detection_tracking=370.4 | feature_ext=40.6 | reid=7.0 | total=418.0 | Tracks: 32
-04-13 15:44:57 [INFO] quit key pressed.
-04-13 15:44:57 [INFO] ... Pipeline finished ...
-04-13 15:44:57 [INFO] Processed 418 frame indices.
-04-13 15:44:57 [INFO] Total time: 212.10s. Overall Avg FPS: 1.97
-04-13 15:44:57 [INFO] OpenCV windows closed.
-04-13 15:44:57 [INFO] Cleaning CUDA cache.
-04-13 15:44:57 [INFO] Exiting.
```

640p



~2.37 fps

```
rack for camera c09 on device '0'
rack for camera c12 on device '0'
rack for camera c13 on device '0'
rack for camera c16 on device '0'
cker instances.

e Processing Loop (using ONNX Detector) ---
h Time: 761.8ms | AvgFPS: 1.31 | Pipeline: preprocess=11.5ms | detection_batched=523.7ms | tracking=5.2ms | feature_ext=179.2ms | total=840.5ms | Tracks: 43
h Time: 341.8ms | AvgFPS: 1.81 | Pipeline: preprocess=8.0ms | detection_batched=282.8ms | postprocess_scale=1.2ms | tracking=8.3ms | total=426.8ms | Tracks: 41
h Time: 426.8ms | AvgFPS: 1.95 | Pipeline: preprocess=7.1ms | detection_batched=278.0ms | tracking=8.0ms | feature_ext=90.5ms | reid=0.0 | total=426.8ms | Tracks: 41
h Time: 359.4ms | AvgFPS: 2.10 | Pipeline: preprocess=7.0ms | detection_batched=278.5ms | postprocess_scale=1.0ms | tracking=7.1ms | total=436.5ms | Tracks: 41
h Time: 382.8ms | AvgFPS: 2.18 | Pipeline: preprocess=7.0ms | detection_batched=278.4ms | postprocess_scale=1.0ms | tracking=8.2ms | total=436.8ms | Tracks: 41
h Time: 354.5ms | AvgFPS: 2.27 | Pipeline: preprocess=7.3ms | detection_batched=278.0ms | postprocess_scale=1.1ms | tracking=7.3ms | total=436.8ms | Tracks: 41
h Time: 352.7ms | AvgFPS: 2.33 | Pipeline: preprocess=7.0ms | detection_batched=279.9ms | tracking=8.2ms | feature_ext=19.1ms | reid=0.0 | total=436.8ms | Tracks: 41
h Time: 331.0ms | AvgFPS: 2.39 | Pipeline: preprocess=6.2ms | detection_batched=279.4ms | tracking=8.2ms | total=293.8ms | ActiveTrackers: 0 | total=436.8ms | Tracks: 41
h Time: 374.8ms | AvgFPS: 2.42 | Pipeline: preprocess=7.3ms | detection_batched=278.4ms | tracking=8.0ms | feature_ext=41.1ms | reid=0.0 | total=436.8ms | Tracks: 41
h Time: 356.5ms | AvgFPS: 2.45 | Pipeline: preprocess=6.2ms | detection_batched=279.4ms | postprocess_scale=1.1ms | tracking=8.1ms | total=436.8ms | Tracks: 41
h Time: 484.3ms | AvgFPS: 2.48 | Pipeline: preprocess=7.3ms | detection_batched=282.8ms | tracking=8.2ms | feature_ext=115.2ms | reid=0.0 | total=436.8ms | Tracks: 41
h Time: 476.9ms | AvgFPS: 2.46 | Pipeline: preprocess=7.3ms | detection_batched=283.8ms | postprocess_scale=1.1ms | tracking=7.6ms | total=436.8ms | Tracks: 41
h Time: 458.2ms | AvgFPS: 2.38 | Pipeline: preprocess=7.1ms | detection_batched=293.4ms | tracking=8.2ms | feature_ext=86.1ms | reid=0.0 | total=436.8ms | Tracks: 41
h Time: 482.2ms | AvgFPS: 2.37 | Pipeline: preprocess=6.2ms | detection_batched=292.0ms | postprocess_scale=1.1ms | tracking=7.2ms | total=436.8ms | Tracks: 41

shed ---
me batches.
s. Overall Avg FPS: 2.37
ndows...
he.
```

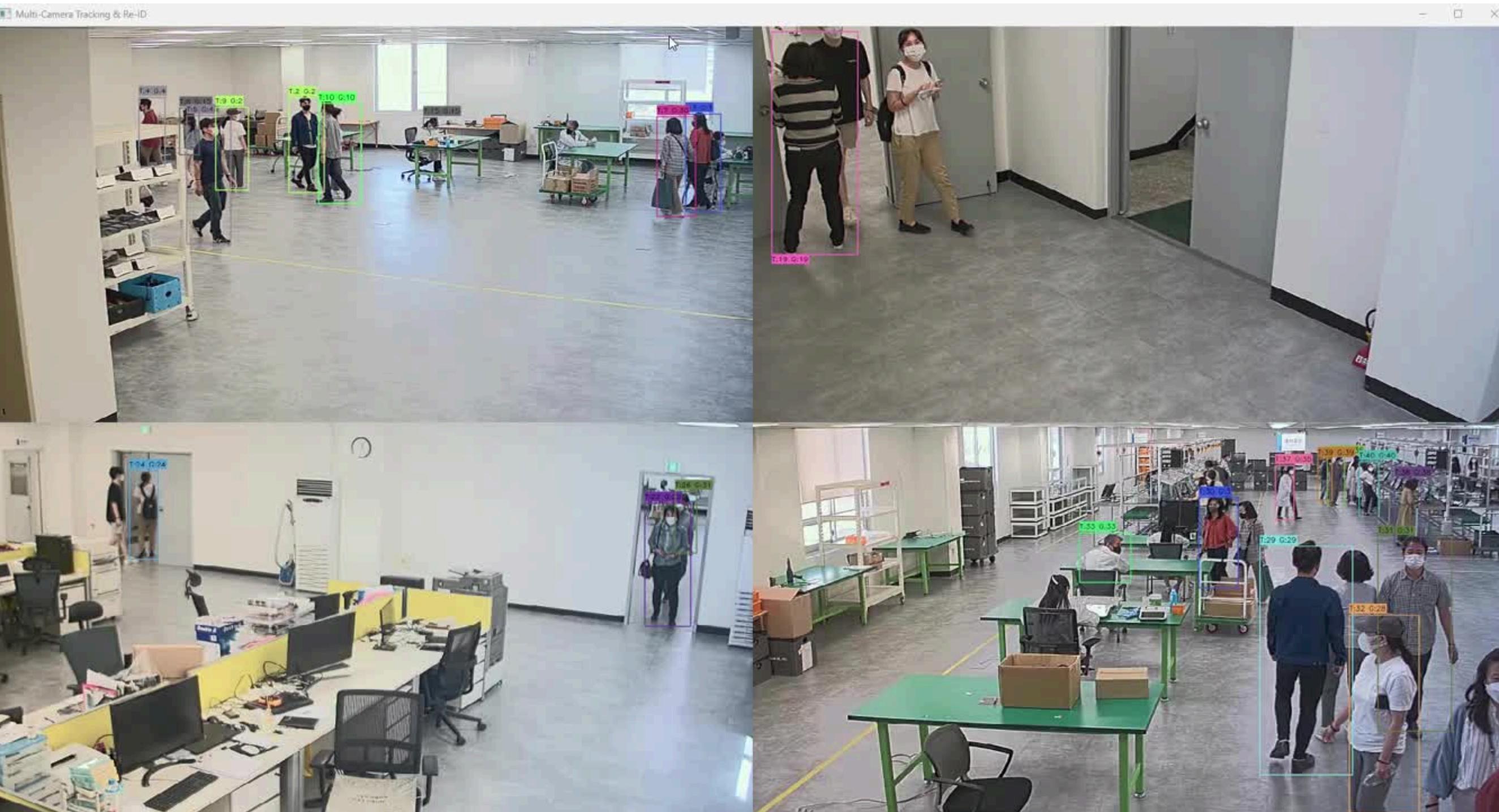
Solution #1

(Compile the model into ONNX)

```
04-13 20:47:30 [INFO] Initialized bytetrack for camera c09 on device '0'
04-13 20:47:30 [INFO] Initialized bytetrack for camera c12 on device '0'
04-13 20:47:30 [INFO] Initialized bytetrack for camera c13 on device '0'
04-13 20:47:30 [INFO] Initialized bytetrack for camera c16 on device '0'
04-13 20:47:30 [INFO] Initialized 4 tracker instances.
04-13 20:47:30 [INFO] --- Starting Frame Processing Loop (using ONNX Detector) ---
04-13 20:47:31 [INFO] Frame 0 | Batch Time: 761.8ms | AvgFPS: 1.31 | Pipeline: preprocess=11.5ms | detection_batched=523.7ms | tracking=5.2ms | feature_ext=179.2ms | total=719.6ms | ActiveTracks: 41
04-13 20:47:31 [INFO] Frame 1 | Batch Time: 341.8ms | AvgFPS: 1.81 | Pipeline: preprocess=8.0ms | detection_batched=282.8ms | postprocess_scale=1.2ms | tracking=8.3ms | total=300.2ms | ActiveTracks: 39
04-13 20:47:31 [INFO] Frame 2 | Batch Time: 426.8ms | AvgFPS: 1.95 | Pipeline: preprocess=7.1ms | detection_batched=278.6ms | tracking=8.0ms | feature_ext=90.5ms | reid=5.1ms | total=389.2ms | ActiveTracks:
04-13 20:47:32 [INFO] Frame 3 | Batch Time: 359.4ms | AvgFPS: 2.10 | Pipeline: preprocess=7.0ms | detection_batched=278.5ms | postprocess_scale=1.0ms | tracking=7.1ms | feature_ext=27.1ms | reid=2.0ms | tota
04-13 20:47:32 [INFO] Frame 4 | Batch Time: 382.8ms | AvgFPS: 2.18 | Pipeline: preprocess=7.0ms | detection_batched=278.4ms | postprocess_scale=1.0ms | tracking=8.2ms | feature_ext=39.2ms | reid=6.1ms | tota
04-13 20:47:32 [INFO] Frame 5 | Batch Time: 354.5ms | AvgFPS: 2.27 | Pipeline: preprocess=7.3ms | detection_batched=278.0ms | postprocess_scale=1.1ms | tracking=7.3ms | feature_ext=20.4ms | reid=1.0ms | tota
04-13 20:47:33 [INFO] Frame 6 | Batch Time: 352.7ms | AvgFPS: 2.33 | Pipeline: preprocess=7.0ms | detection_batched=279.9ms | tracking=8.2ms | feature_ext=19.1ms | reid=2.0ms | total=316.2ms | ActiveTracks:
04-13 20:47:33 [INFO] Frame 7 | Batch Time: 331.6ms | AvgFPS: 2.39 | Pipeline: preprocess=6.2ms | detection_batched=279.4ms | tracking=8.2ms | total=293.8ms | ActiveTracks: 39
04-13 20:47:33 [INFO] Frame 8 | Batch Time: 374.8ms | AvgFPS: 2.42 | Pipeline: preprocess=7.3ms | detection_batched=278.4ms | tracking=8.0ms | feature_ext=41.1ms | reid=4.0ms | total=338.8ms | ActiveTracks:
04-13 20:47:34 [INFO] Frame 9 | Batch Time: 356.5ms | AvgFPS: 2.45 | Pipeline: preprocess=6.2ms | detection_batched=279.4ms | postprocess_scale=1.1ms | tracking=8.1ms | feature_ext=21.5ms | reid=2.1ms | tota
04-13 20:47:50 [INFO] Frame 50 | Batch Time: 484.3ms | AvgFPS: 2.48 | Pipeline: preprocess=7.3ms | detection_batched=282.8ms | tracking=8.2ms | feature_ext=115.2ms | reid=35.3ms | total=448.7ms | ActiveTracks
04-13 20:48:11 [INFO] Frame 100 | Batch Time: 476.9ms | AvgFPS: 2.46 | Pipeline: preprocess=7.3ms | detection_batched=283.8ms | postprocess_scale=1.1ms | tracking=7.6ms | feature_ext=93.5ms | reid=44.0ms | tot
04-13 20:48:33 [INFO] Frame 150 | Batch Time: 458.2ms | AvgFPS: 2.38 | Pipeline: preprocess=7.1ms | detection_batched=293.4ms | tracking=8.2ms | feature_ext=86.1ms | reid=23.2ms | total=418.1ms | ActiveTracks:
04-13 20:48:54 [INFO] Frame 200 | Batch Time: 482.2ms | AvgFPS: 2.37 | Pipeline: preprocess=8.2ms | detection_batched=292.6ms | postprocess_scale=1.1ms | tracking=7.2ms | feature_ext=108.1ms | reid=24.6ms | to
04-13 20:49:05 [INFO] Quit key pressed.
04-13 20:49:05 [INFO] --- Pipeline Finished ---
04-13 20:49:05 [INFO] Processed 225 frame batches.
04-13 20:49:05 [INFO] Total time: 94.81s. Overall Avg FPS: 2.37
04-13 20:49:05 [INFO] Closing OpenCV windows...
04-13 20:49:05 [INFO] Clearing CUDA cache.
04-13 20:49:05 [INFO] Exiting.
```

ONNX 640p, FPS: 2.37

Solution #1 (Detection frame skipping)

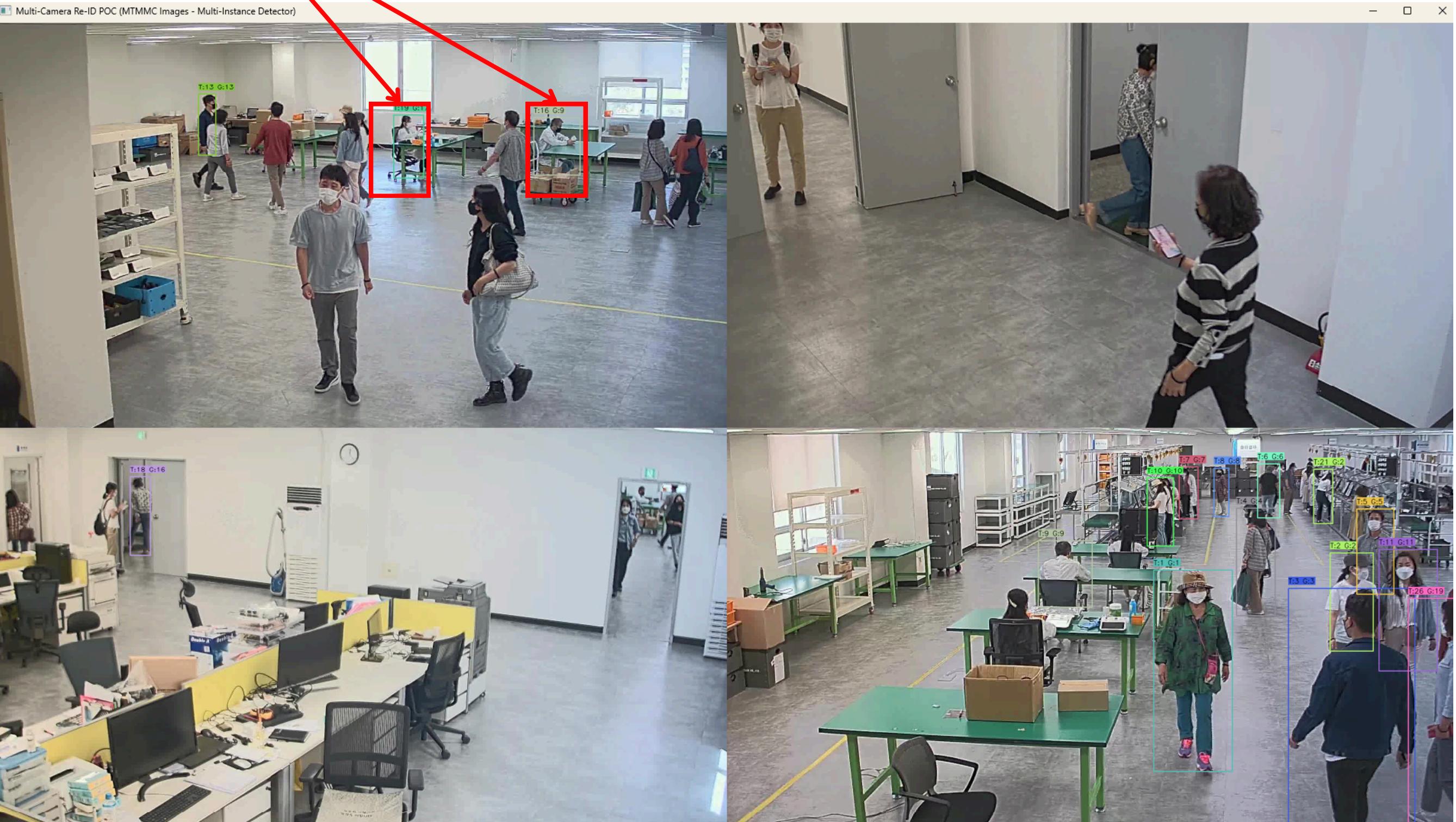


Skip rate = 3, FPS: 6.11

Problem #2: Re-ID conflict

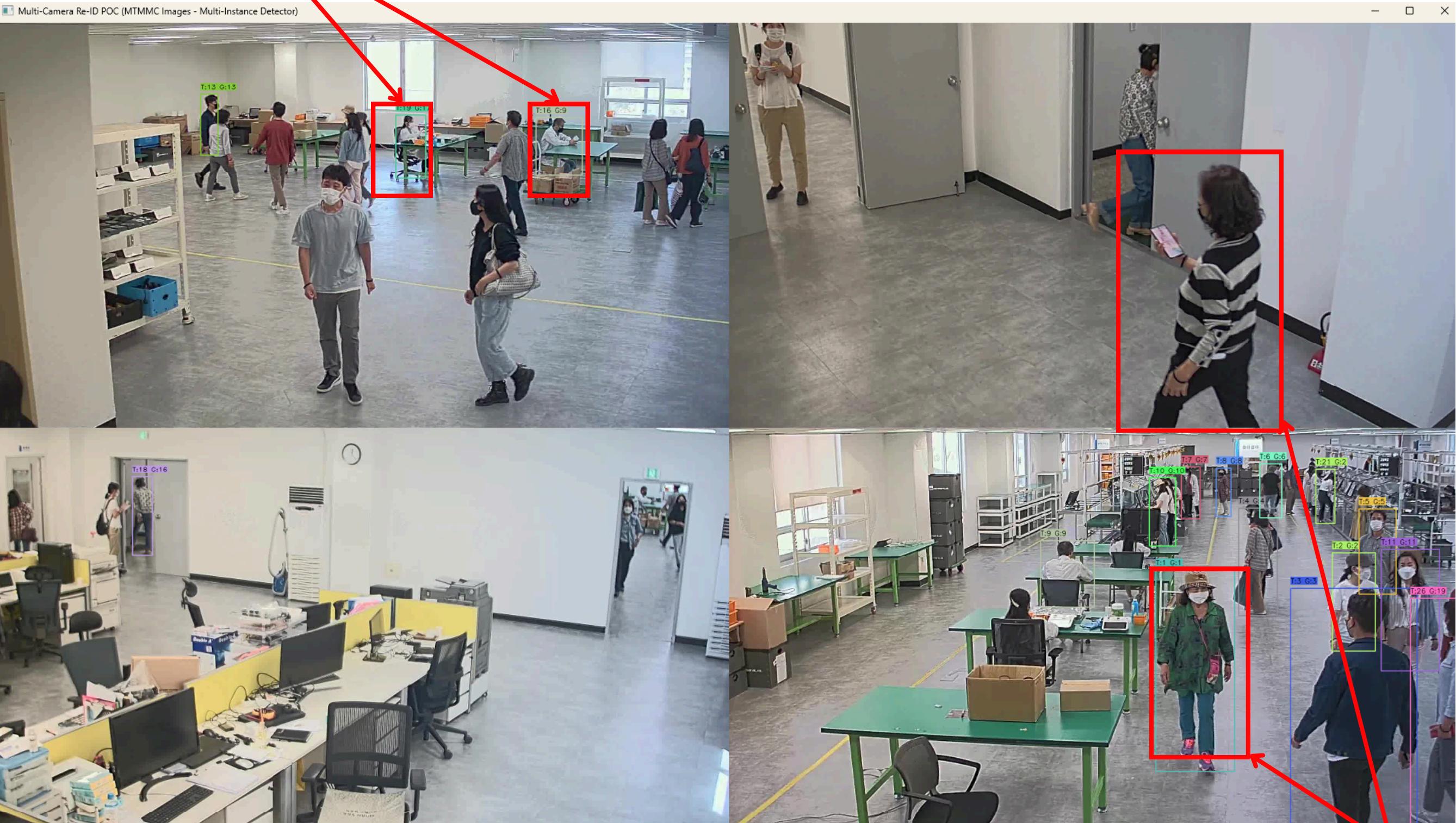
Same Global ID

Problem #2



Same Global ID

Problem #2

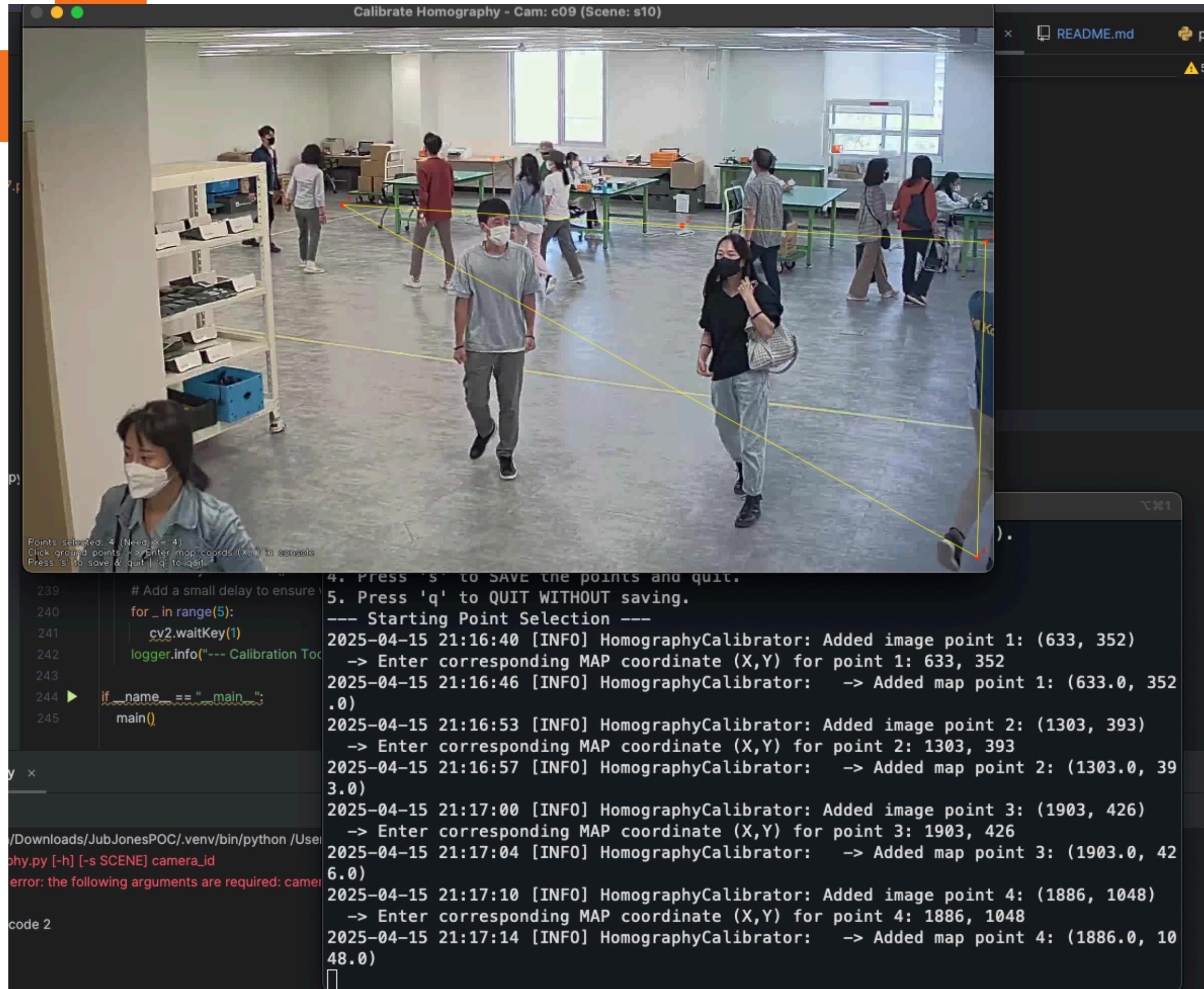


Comparing impossible case

Solution #2 (Cross-Camera Handoff Candidate)

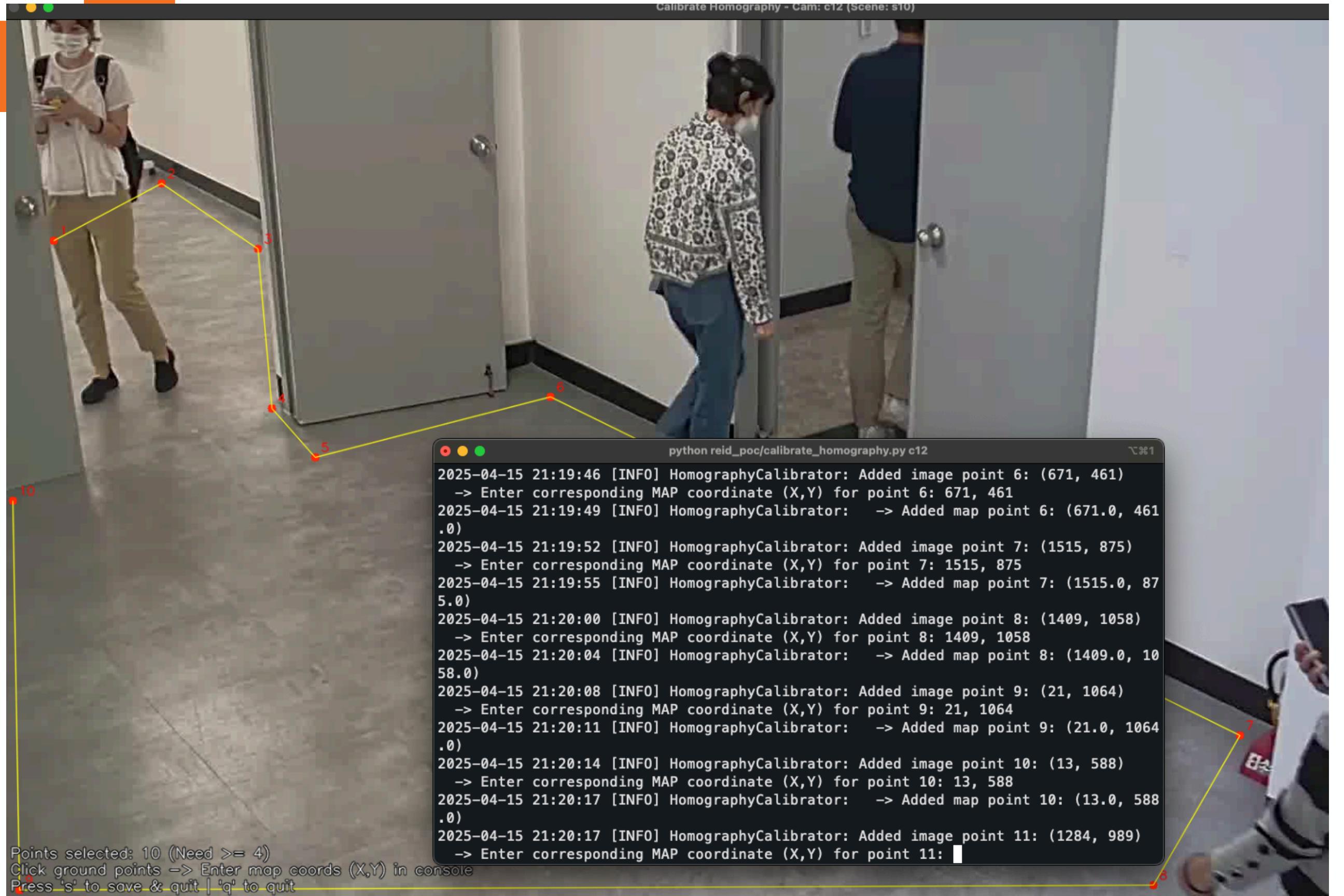


Unified Spatial Mapping



Calibrate Homography

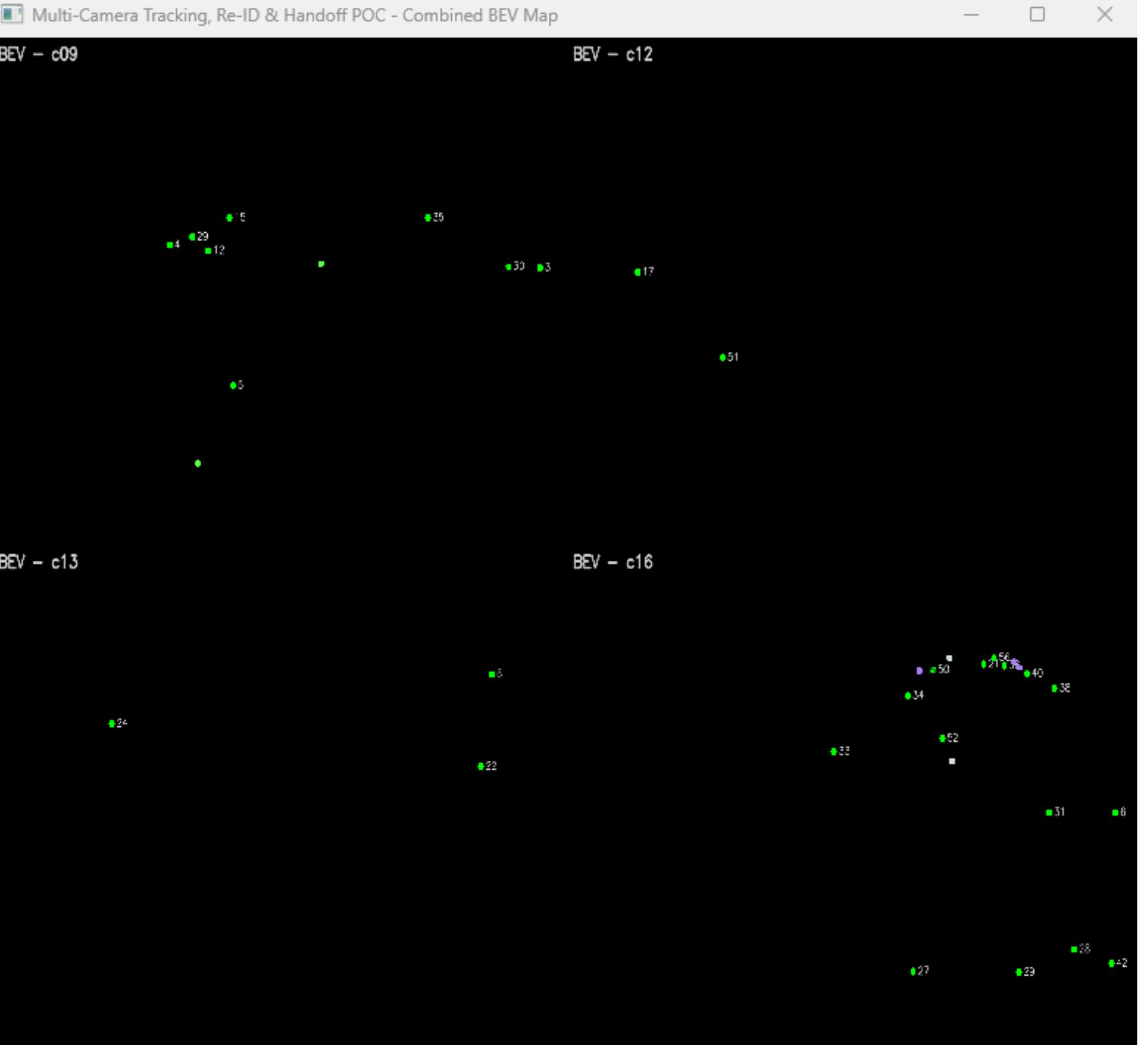
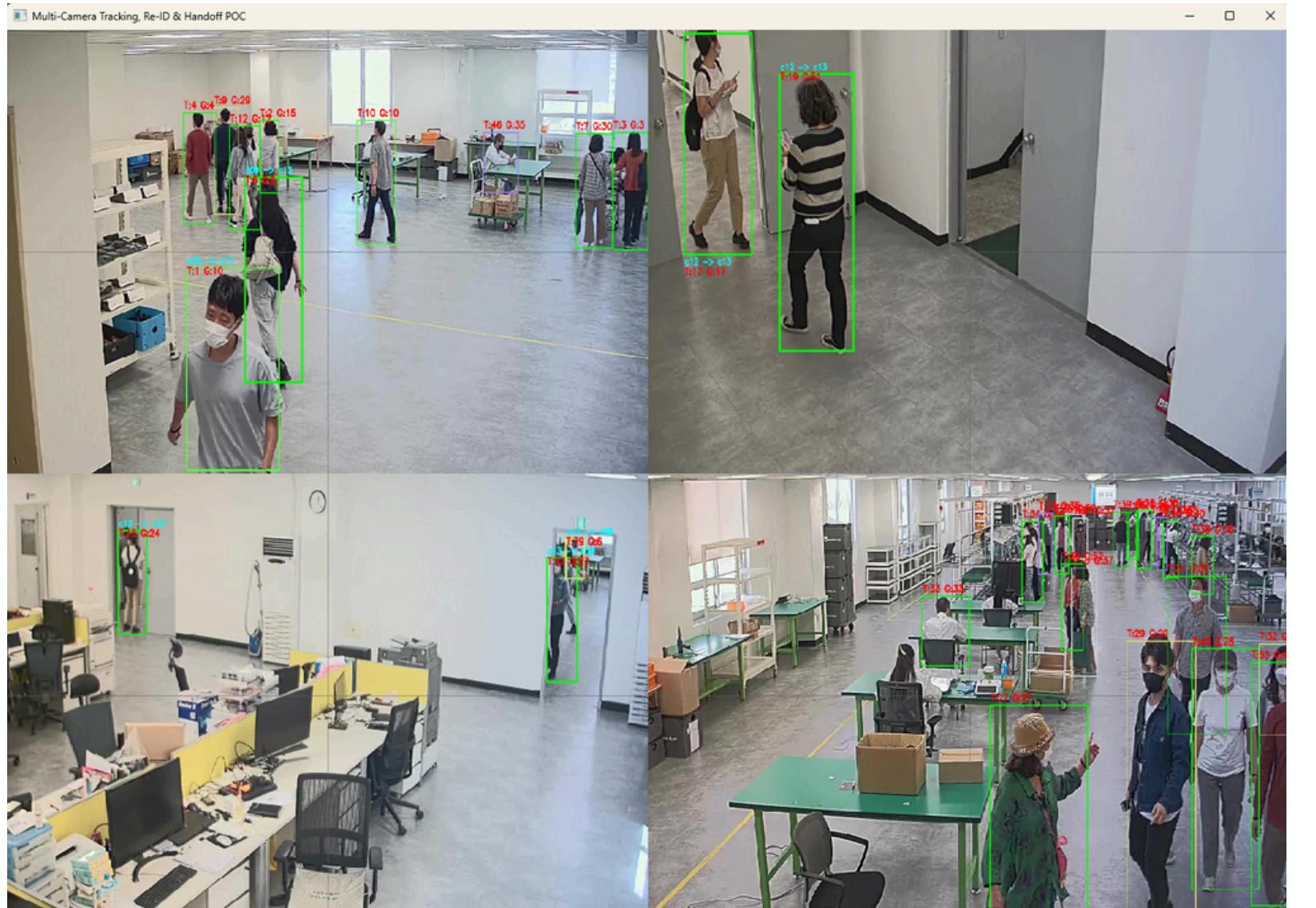
(Getting the ground)



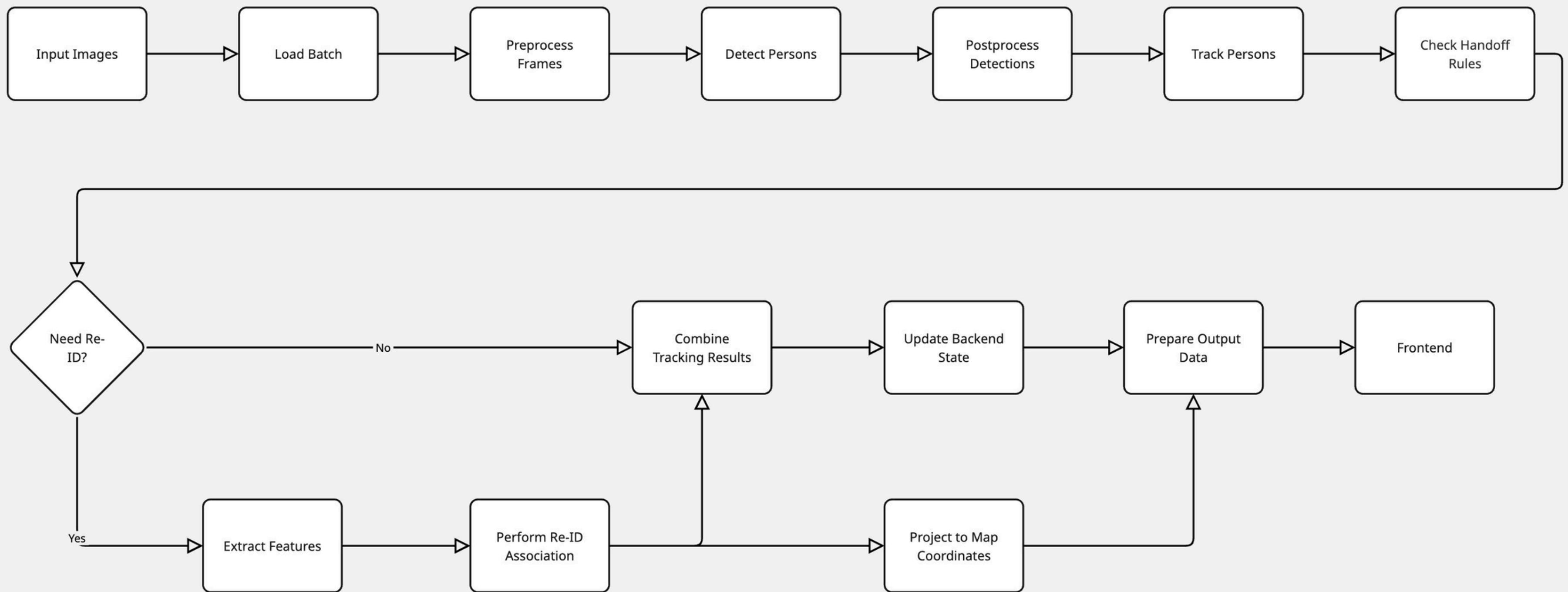
Calibrate Homography

(Getting the ground)

Result



Data Flow



What's next

- MLOPs designing
- ReID models evaluation
- SDD