Latency-Aware 360-Degree Video Analytics Framework for First Responders Situational Awareness

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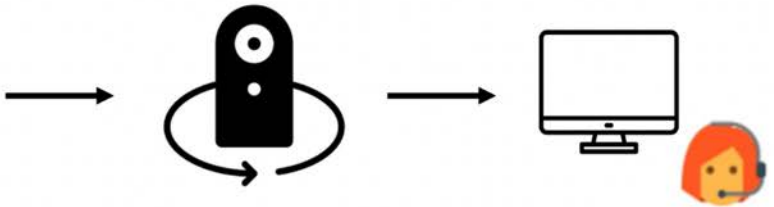
Background: First Responder Training

Training Field

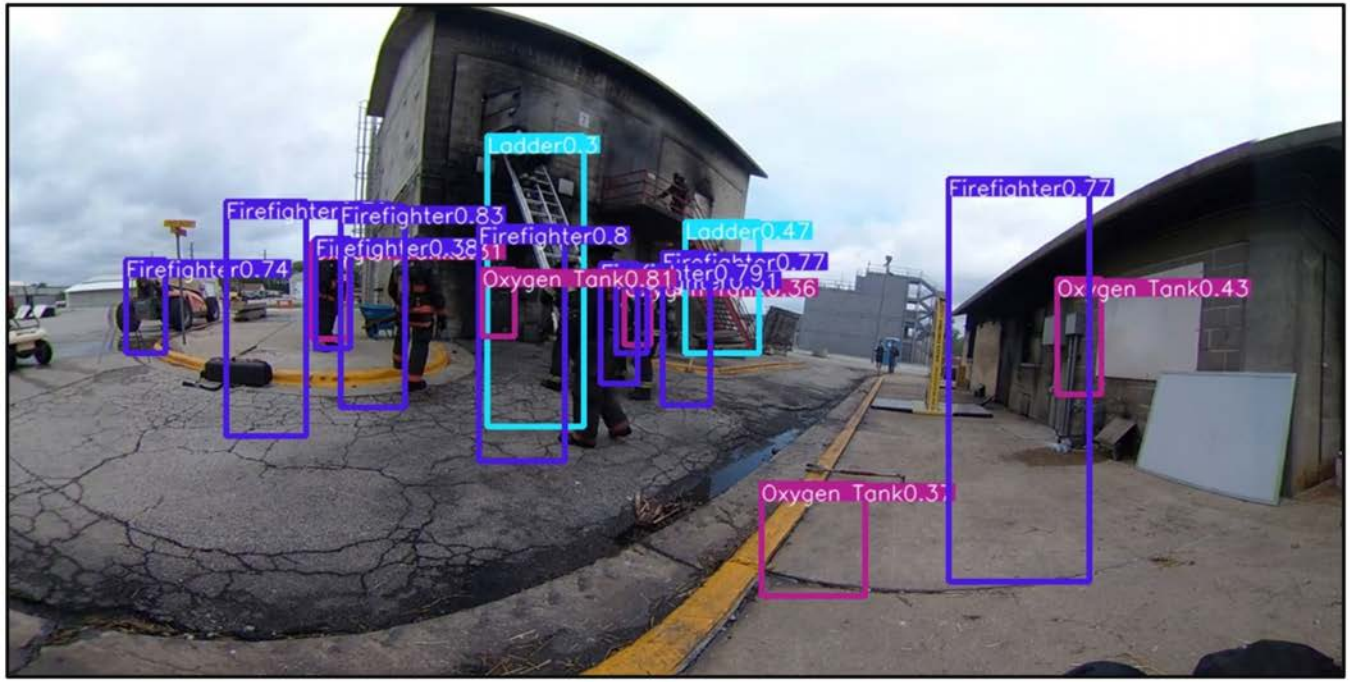


Background: First Responder Training

Object of Interest	Priority
Civilian	High
Fire	High
Smoke	High
Gas Mask	High
Firefighter	Low
Helmet	Low

Data based on an interview with a physical training instructor at Illinois Fire Service Institute (IFSI)

Viewing and Query Service



Searching for Objects

Car

Found **3 Cars** in this video:

00:33 00:50 01:23

Labeling Objects

Firefighter	✓	Civilian	○
Oxygen	✓	Ladder	✓
Helmet	○	Car	○

Our focus – **Object Detection**

360 Video Object Detection via 2D Object Detectors

Geometric Distortion

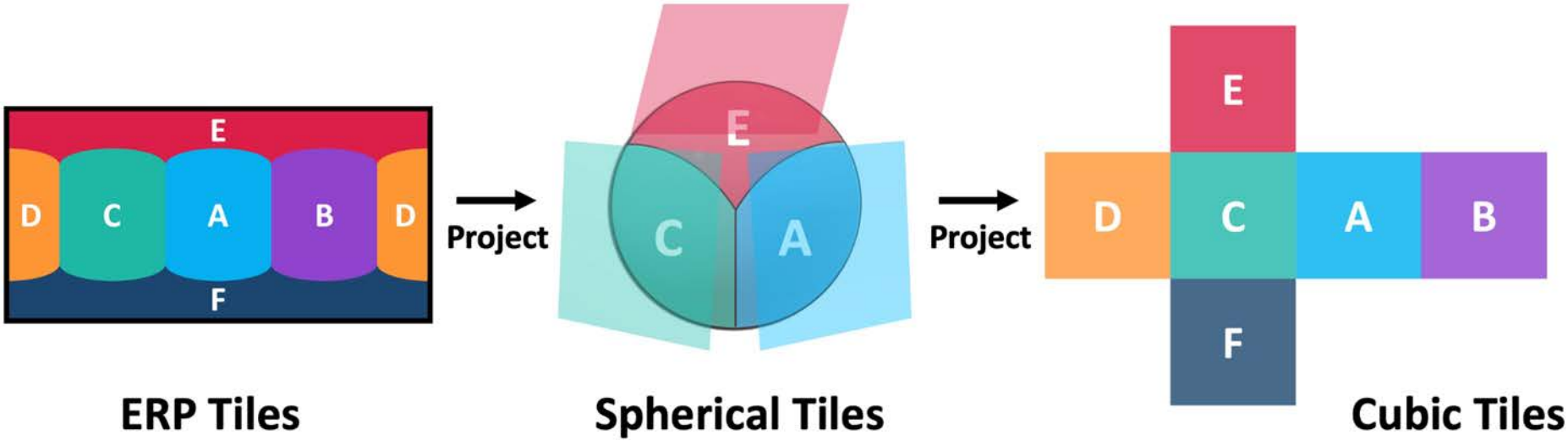
(Detection Error)

(Missed Detection)

Frame Size

- 4 times the number of pixels of a normal 1080p video

Dual-Projection Solution for 2D Object Detector Issues



Normal field of view

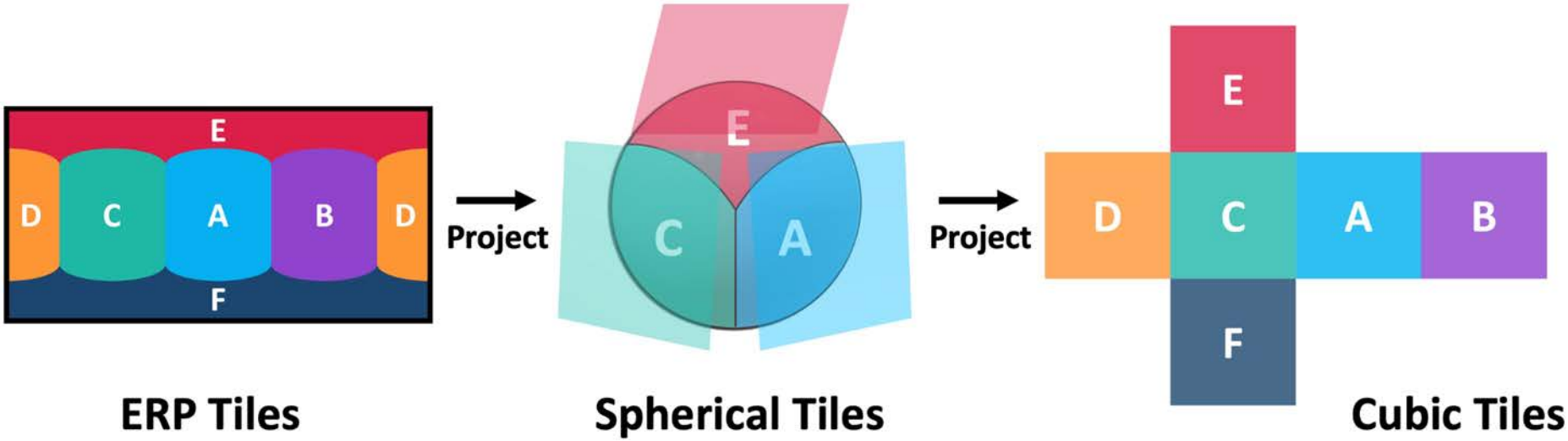
Dual-Projection Examples

ERP Tiles

Dual-Projection

Cubic Tiles

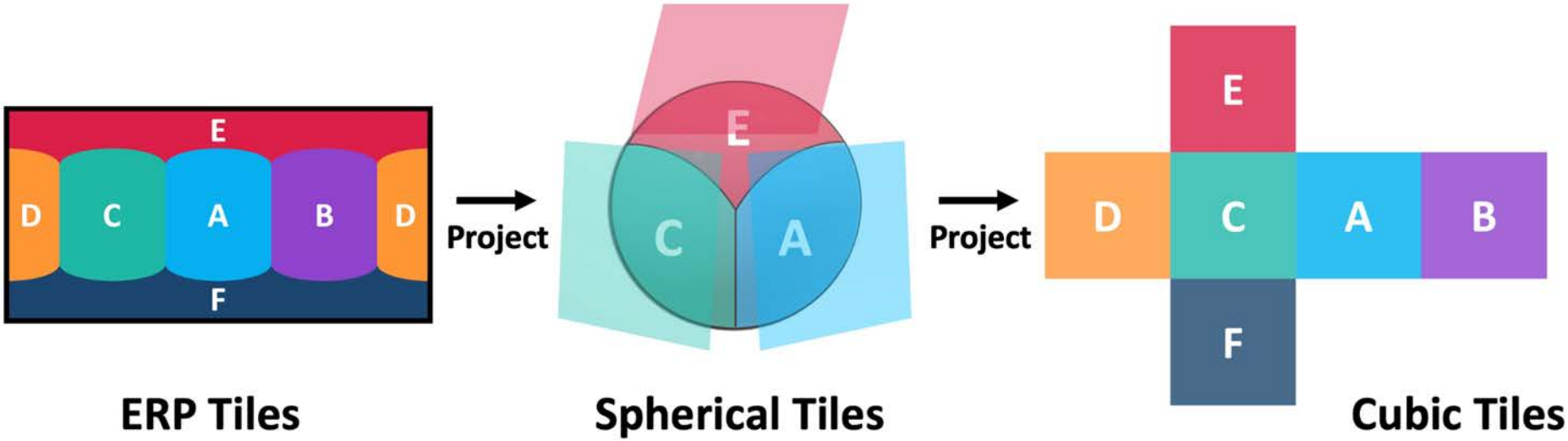
Dual-Projection Limitations



Leads to extra processing time in transforming ERP tiles to cubic tiles

E.g., >30% extra time on a 4-core CPU

Dual-Projection



Leads to extra processing time in transforming ERP tiles to cubic tiles

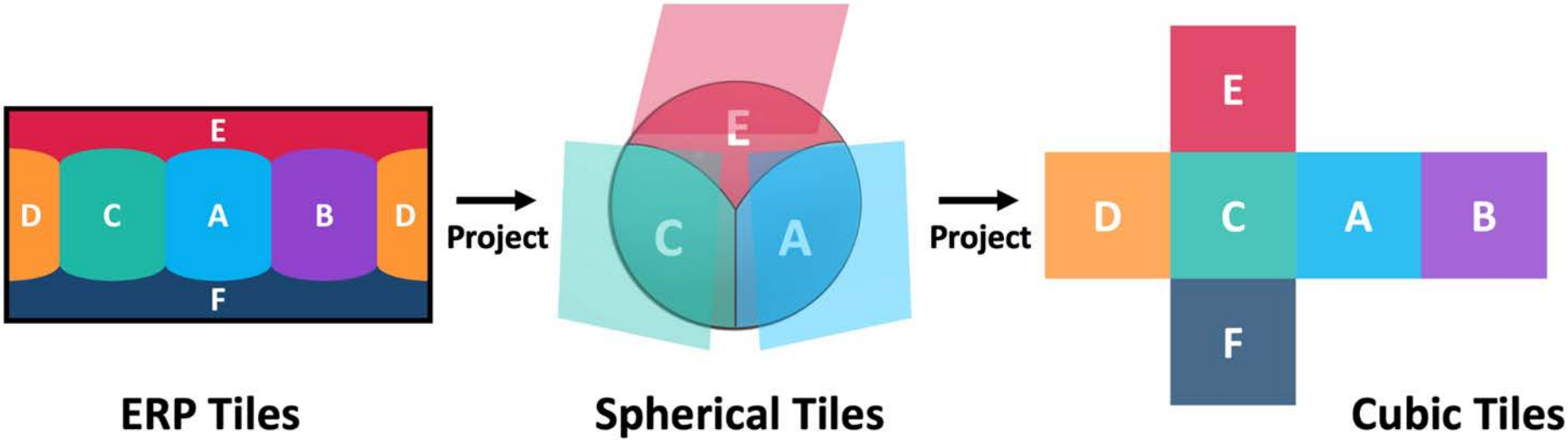
Dynamic Selection: filters out unnecessary projection and detection.

Dynamic Selection: Overview

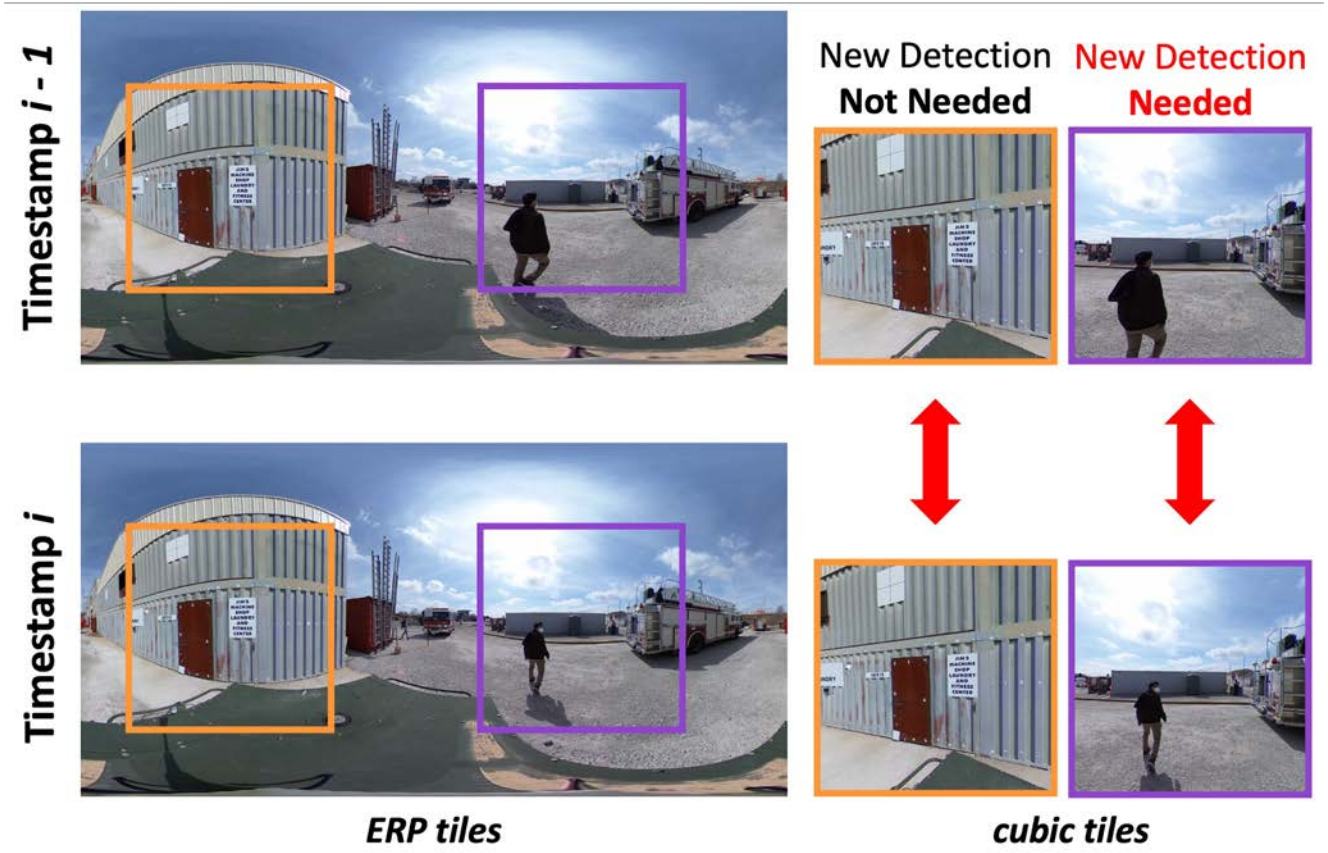
Detect on ***cubicTile***$_{i,j}$ (*cubic tile j* at timestamp *i*) only when

- Condition (1) ***cubicTile***$_{i,j}$ is structurally different from ***cubicTile***$_{i-1,j}$
- Condition (2) ***cubicTile***$_{i-1,j}$ contains a high *object cohesion*

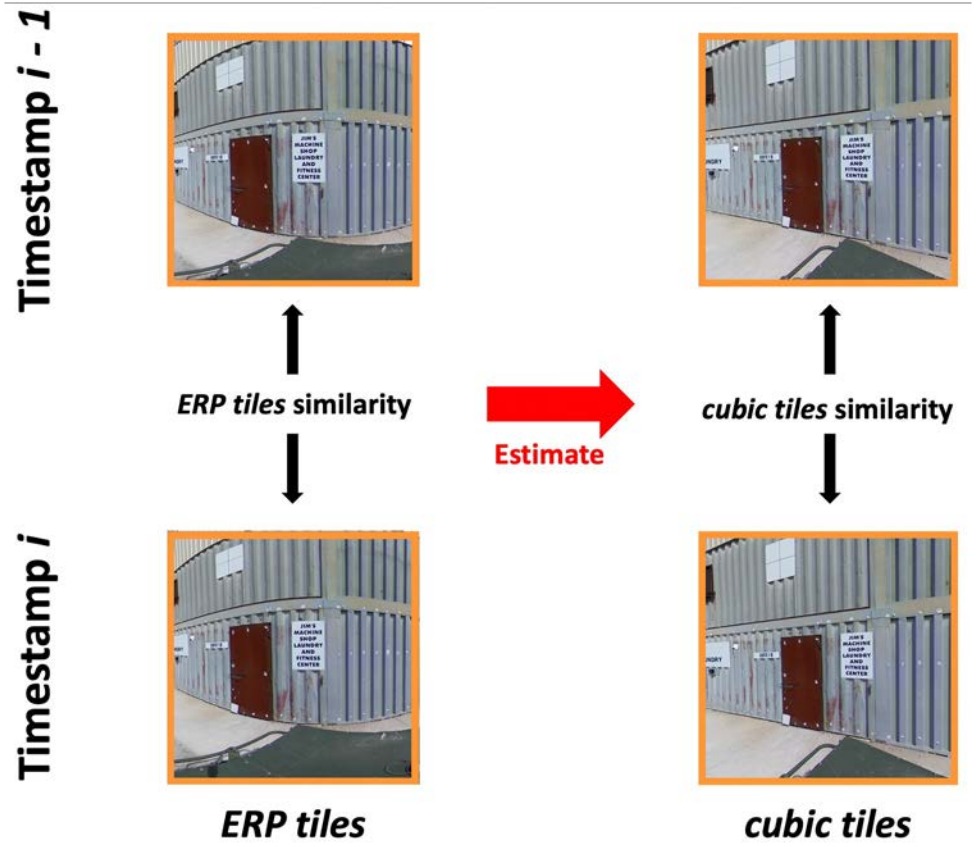
Otherwise, inference result of the previous timestamp is adopted for ***cubicTile***$_{i,j}$



Inter-Frame Similarity (*sim*): Motivation



Inter-Frame Similarity (*sim*): Estimation

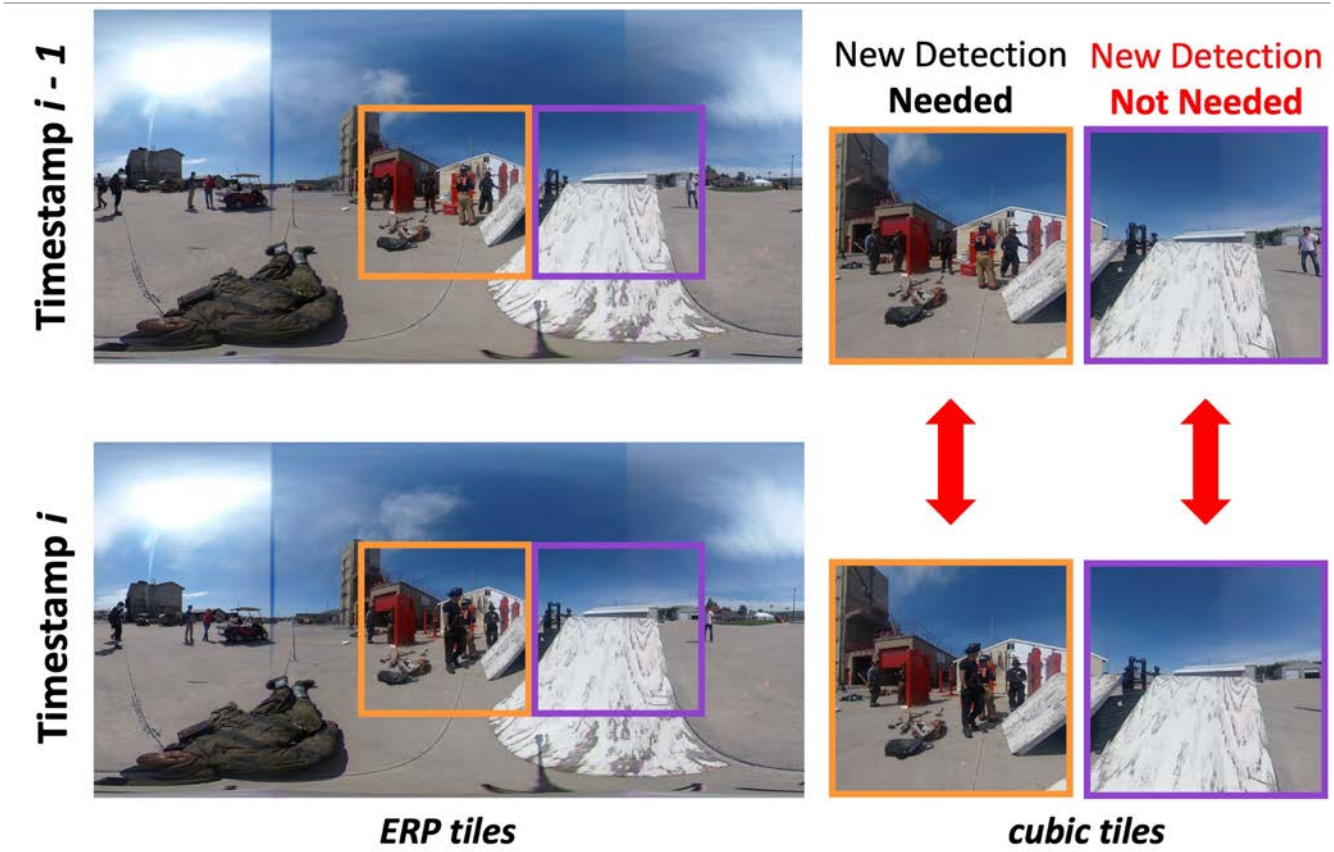


Inter-Frame Similarity (*sim*): Distortion Correction

$$x' = x \cdot \frac{pixel\ sample\ rate}{center\ sample\ rate} = x \cdot \frac{2\pi r cos(\theta)}{2\pi r} = x \cdot cos(\theta)$$

$$sim(cubicTile_{i-1j}, cubicTile_{ij}) = NRMSE(erpTile'_{i-1j}, erpTile'_{ij})$$

Object Cohesion (oc): Motivation



Object Cohesion (oc): Formula

oc measures **if any objects will remain in the *cubic tile* in the next timestamp**

Factors affecting the *oc*:

- Number of objects
- Distance of the object to the cubic tile center (d_o)
- Object size (s_o)
- Confidence level (c_o)

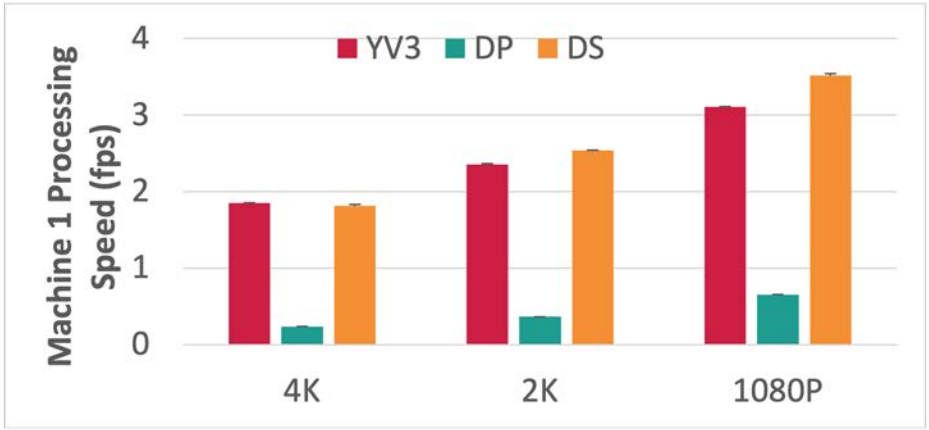
$$oc(cubicTile_{ij}) = \sum_{object\ o} \frac{c_o}{s_o \cdot d_o}$$

Models for Evaluation

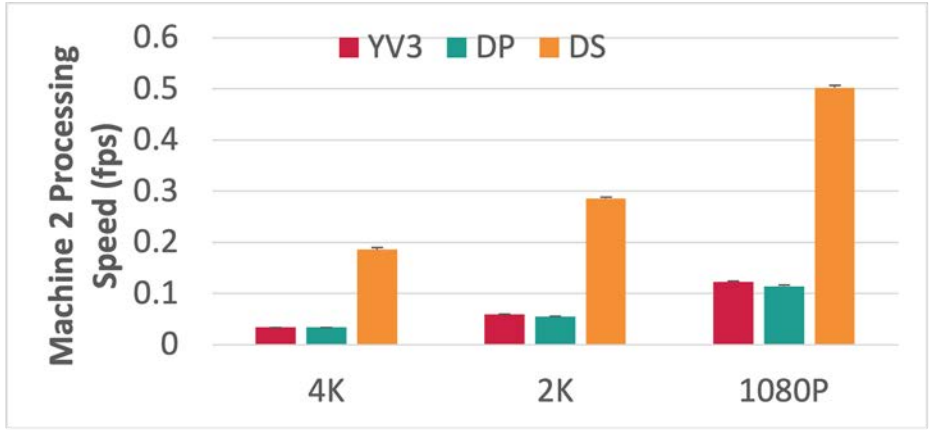
- **YV3**: Detecting using the **YOLOv3** model on **ERP** frames
- **DP**: Detecting using the **YOLOv3** model on cubic tiles generated by the **Dual-Projection** process
- **DS**: Our approach, detecting using the **YOLOv3** model on cubic tiles generated by the **Dynamic Selection** algorithm
- A dataset of 25 360-degree videos collected at Illinois Firefighter Service Institute (19 training; 6 testing)
- One 6-core CPU with a 12GB GBP and one 4-core CPU without a GPU

Evaluation of Processing Speed

NVIDIA GeForce RTX 3080 Ti

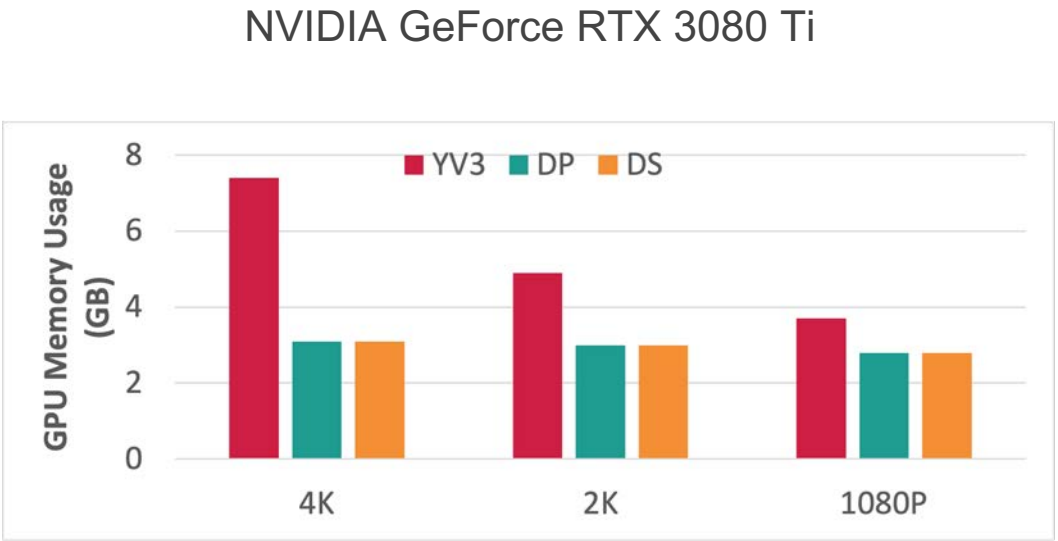


No GPU



More than 4x speed up over dual projection on GPU and non-GPU machines

Evaluation of Memory Utilization



Over 25% reduction in GPU memory (<4GB) compared to YV3, making high-resolution detection accessible to mid/low-end hardware

Evaluation of Detection Accuracy

Improved detection accuracy compared to YV3 (selected classes)

Conclusion

- **360 Video Object Detection Challenges**
  - Geometric Distortion
  - High Computation

- **Our Contribution: Dynamic Selection**
  - >4X Speedup
  - >25% memory usage reduction
  - Improved detection accuracy

(Missed Detection due to Distortion)

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