



Anyone here? Smart embedded low-resolution omni-directional video sensor to measure room occupancy

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Current solution - PIR sensors

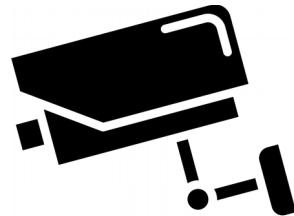
The screenshot shows a web-based application for managing meeting rooms. On the left is a detailed floor plan of a building with various rooms labeled (e.g., F602, F651, F665, F663, F661, F573, F575, F567, F568, F569, F562, F556, F520, F528). Colored overlays indicate room status: red for occupied, green for free, and grey for unknown. Below the floor plan is a legend: "Someone is present" (red), "Nobody present, no meeting" (green), and "Nobody present, meeting booked" (yellow). A checkbox for "Colour blind?" is also present. To the right of the floor plan is a table listing room numbers and their current status:

Room	Status
F520	free
F661	free
F663	free
F562	occupied
F602	occupied
F651	occupied
F665	occupied
F663	unknown
F661	unknown
F573	unknown
F575	unknown
F520	unknown
F528	unknown
F556	unknown
F567	unknown
F568	unknown
F569	unknown
F573	unknown
F575	unknown
F620	unknown

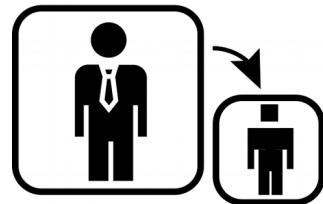


- ✓ No privacy issues
- ✓ Easy to install
- ✓ Cheap
- ✗ Requires a level of movement
- ✗ Binary output (YES / NO)
- ✗ No people count

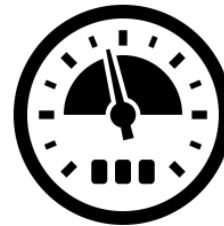
Research Overview



Camera



High ↘ Low

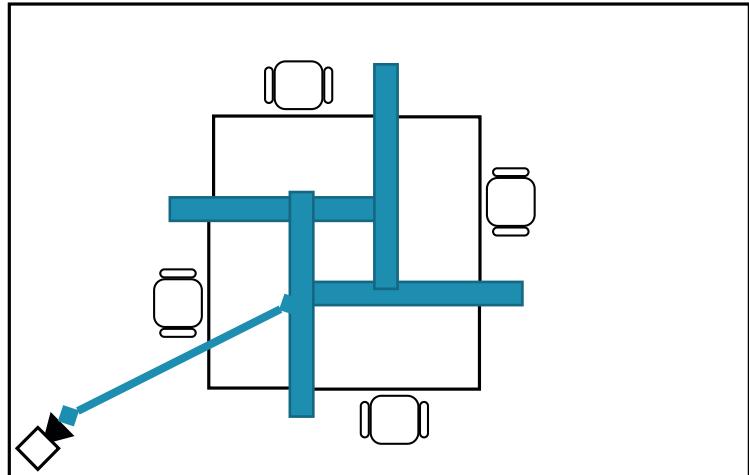
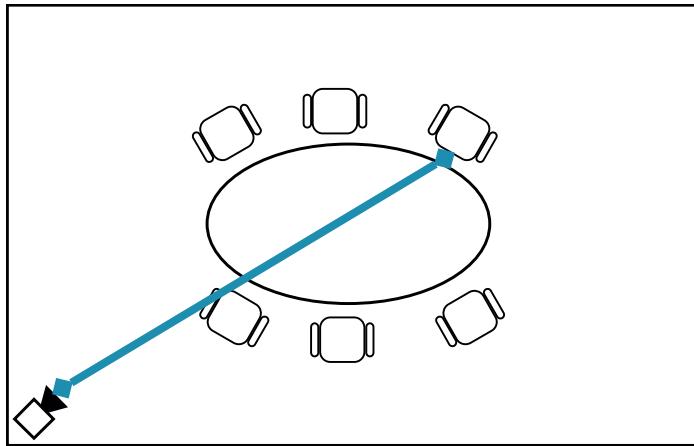


Performance

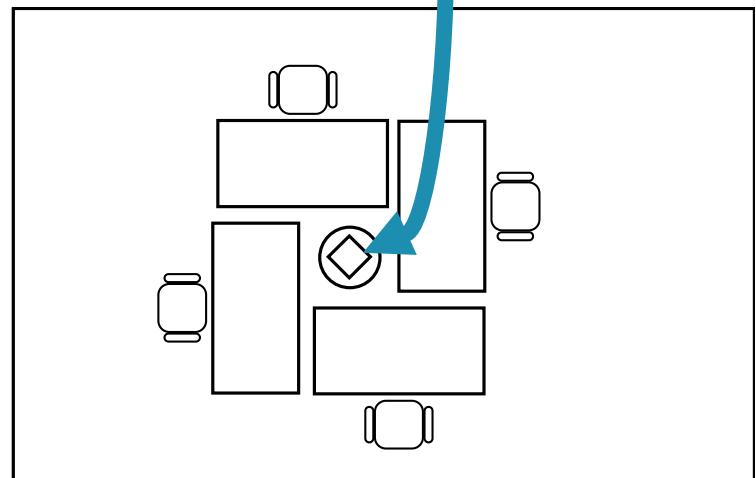
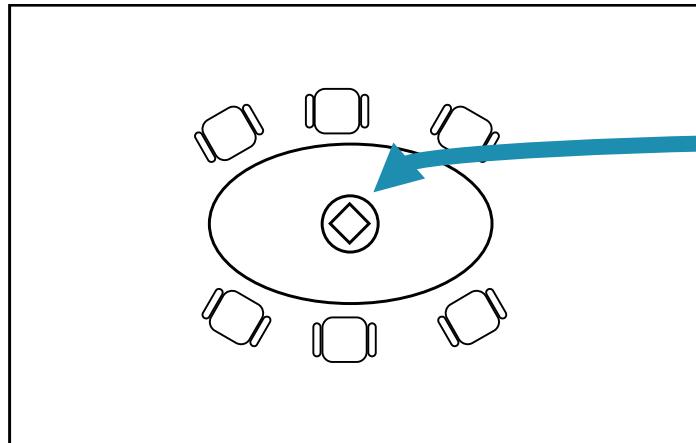


Privacy

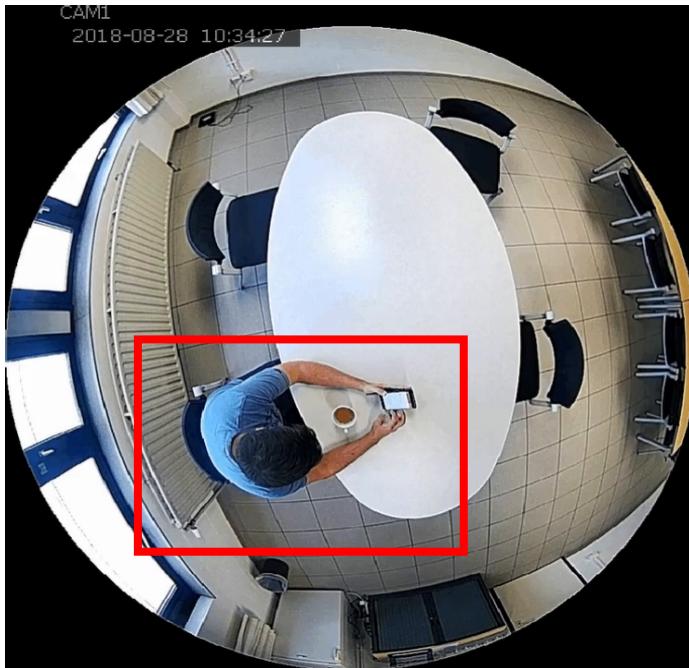
Camera



Camera

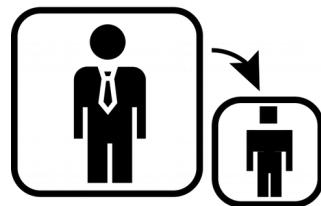


Camera

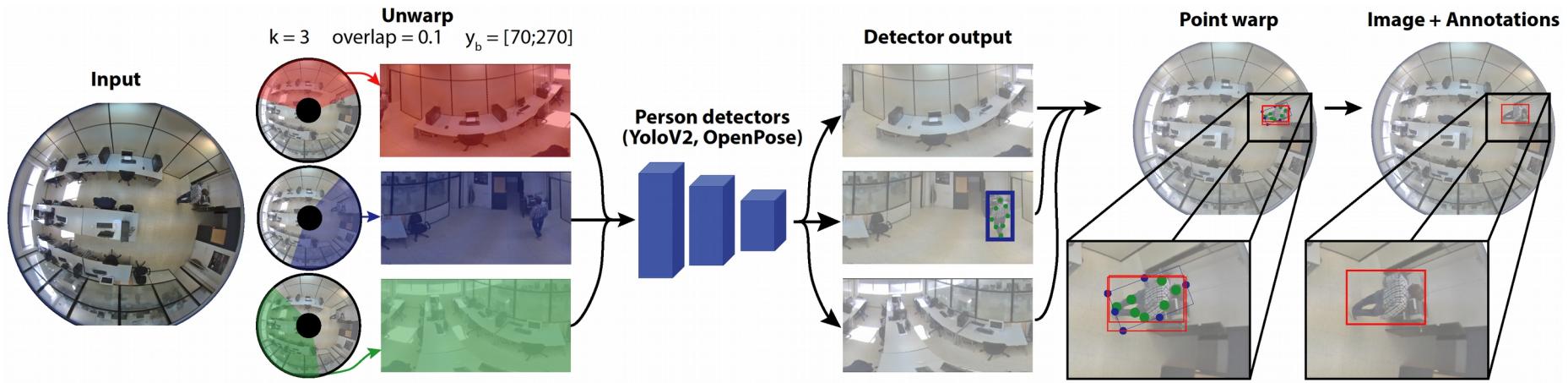


- ✓ Large field-of-view
- ✓ Single camera
- ✗ Image distortion
- ✗ Limited number of annotated datasets

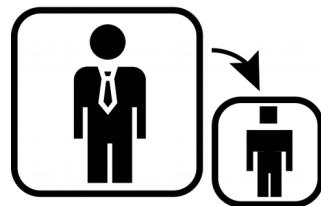
Can we count people using these images?



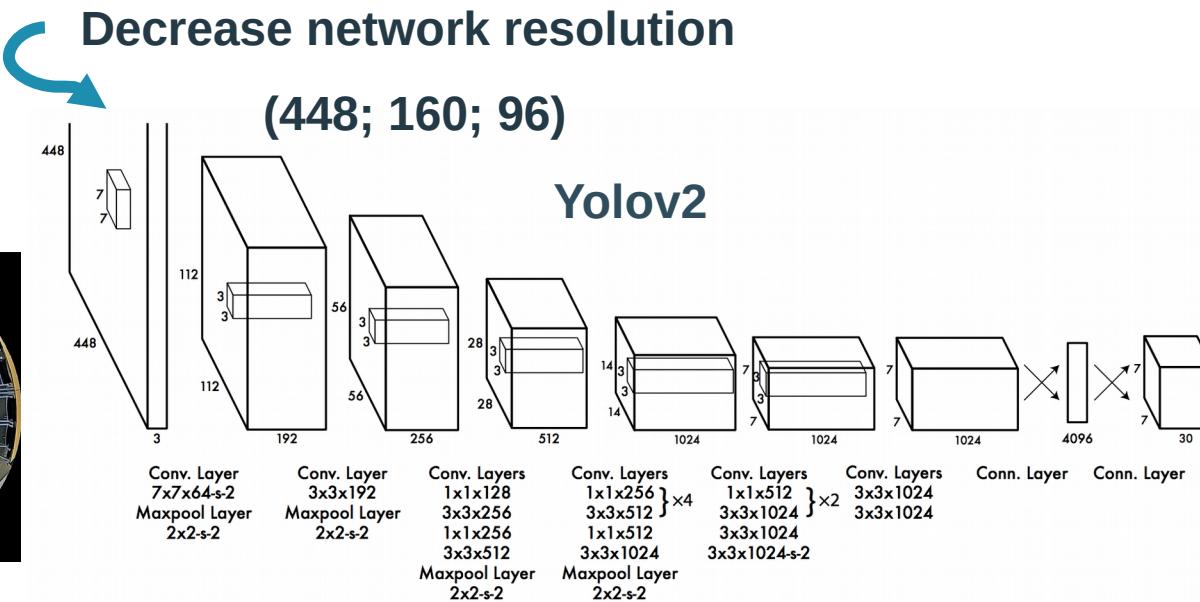
Approach – Generating data

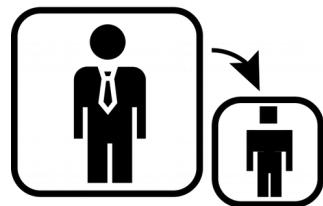


Zhe Cao et al. "OpenPose: realtime multi-person 2D pose estimation using Part Affinity Fields" 2018 (CVPR)
Redmond et al. "YOLO9000: Better, Faster, Stronger" 2017 (CVPR)



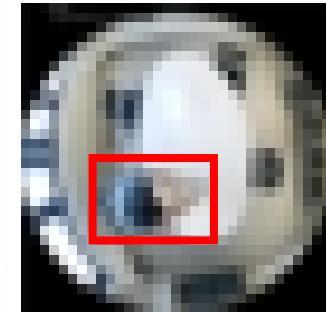
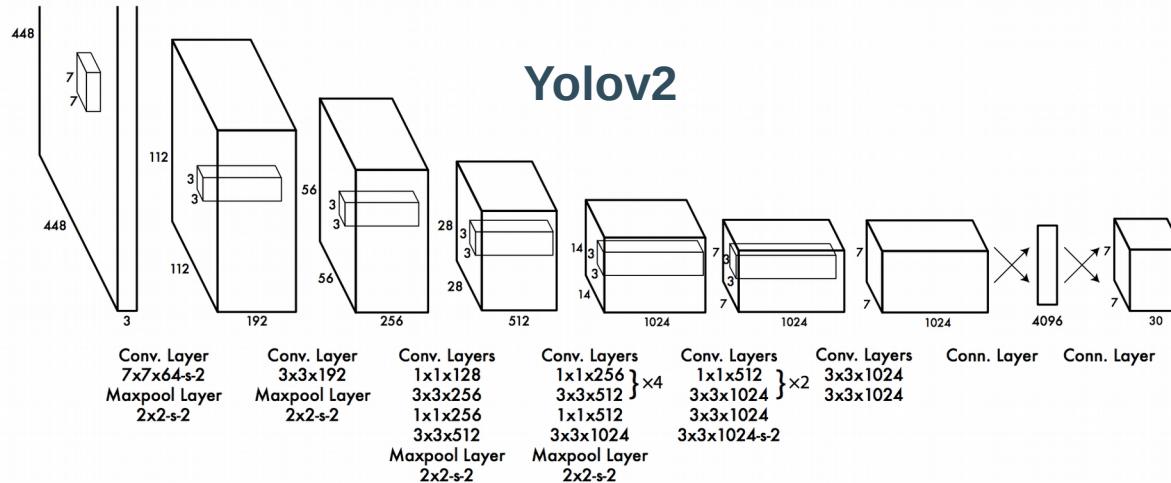
Approach – Lowering network resolution





Approach – Lowering image resolution

Decrease image resolution
(64; 48; 32)



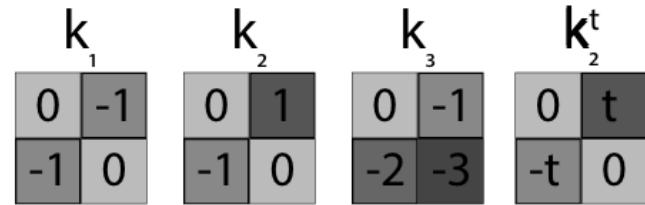
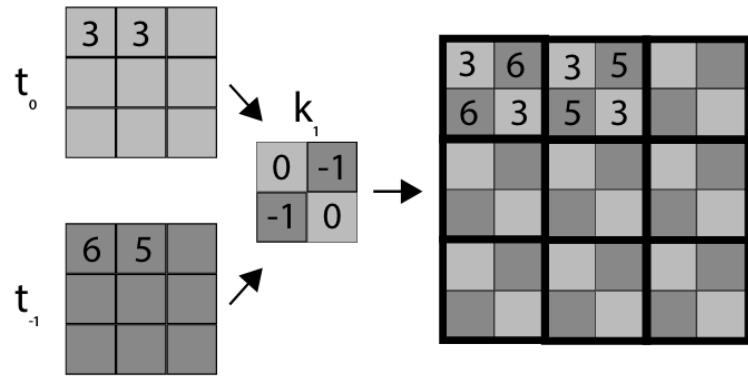
Redmond et al. "YOLO9000: Better, Faster, Stronger" 2017 (CVPR)



Approach – Using temporal data

People move
vs.
Static background

Can we improve our system by
integrating temporal information?





Performance

448

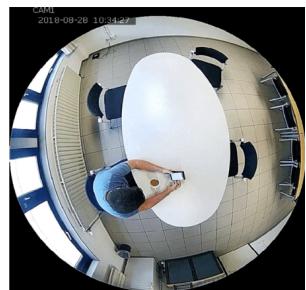
160

96

64

48

32



Device	Resolution	Seconds per Frame
Raspberry Pi 2	448	18.60
	160	3.60
	96	2.17
Raspberry Pi 3B	448	16.60
	160	2.96
	96	1.83
Raspberry Pi 3B+	448	11.72
	160	2.07
	96	1.30



Results

Test on model trained with generated labels

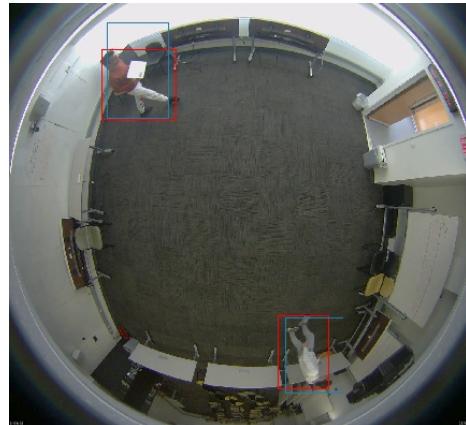
- Different network resolutions
- Different image resolutions



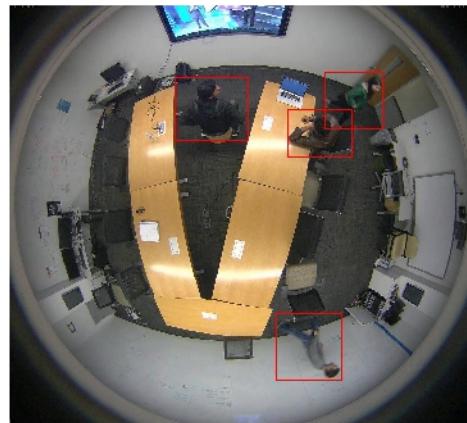
PIROPO



PRIVATE OFFICE



MIRROR A



MIRROR B

PIROPO - <https://www.gti.ssr.upm.es/research/gti-data/databases>
MirrorChallenge - <https://www.hcd.icat.vt.edu/mirrorworlds/challenge/index.html>



Results

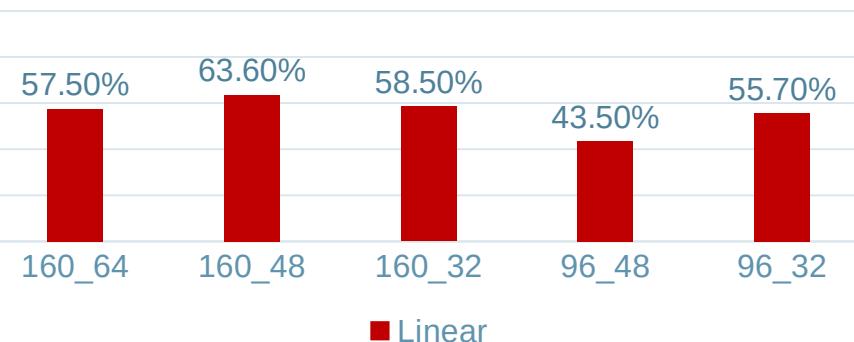
PIROPO



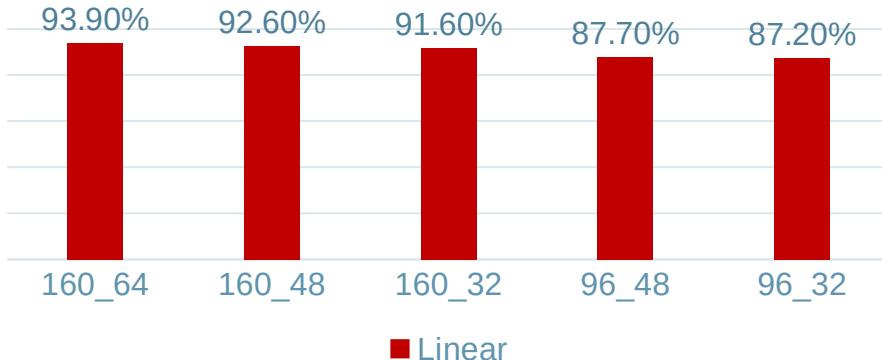
PRIVATE



MIRROR A



MIRROR B



Results

$$\begin{array}{c} k_1 \quad k_2 \quad k_3 \quad k^t \\ \begin{matrix} 0 & -1 \\ -1 & 0 \end{matrix} \quad \begin{matrix} 0 & 1 \\ -1 & 0 \end{matrix} \quad \begin{matrix} 0 & -1 \\ -2 & -3 \end{matrix} \quad \begin{matrix} 0 & t \\ -t & 0 \end{matrix} \end{array}$$



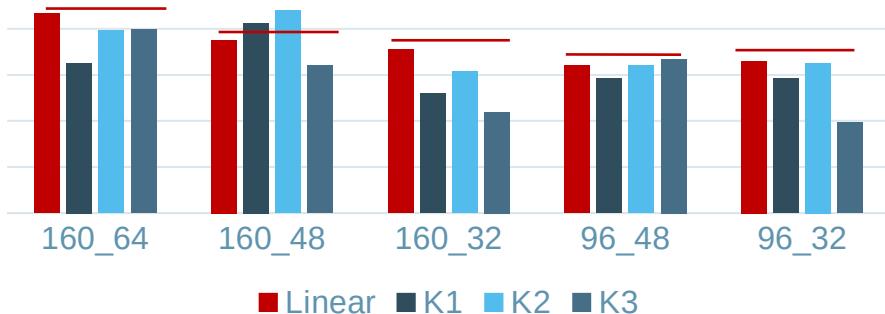
PIROPO

High movement level



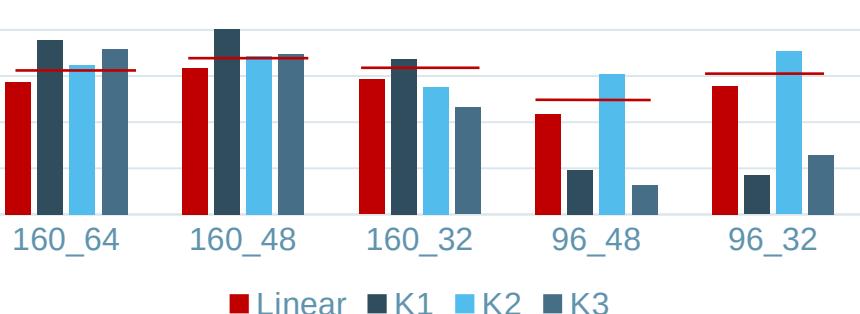
PRIVATE

Low movement level



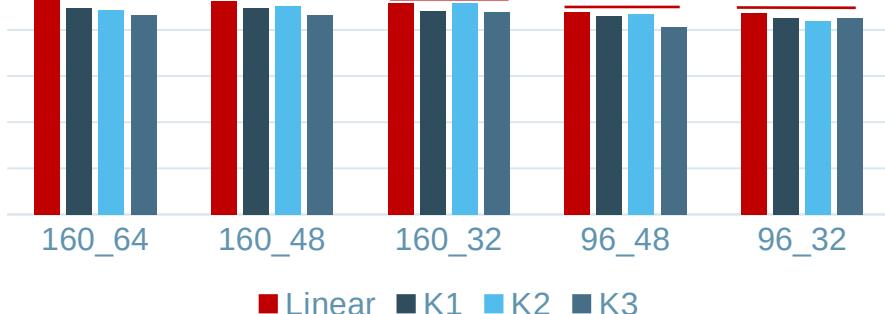
MIRROR A

Medium movement level



MIRROR B

Medium movement level

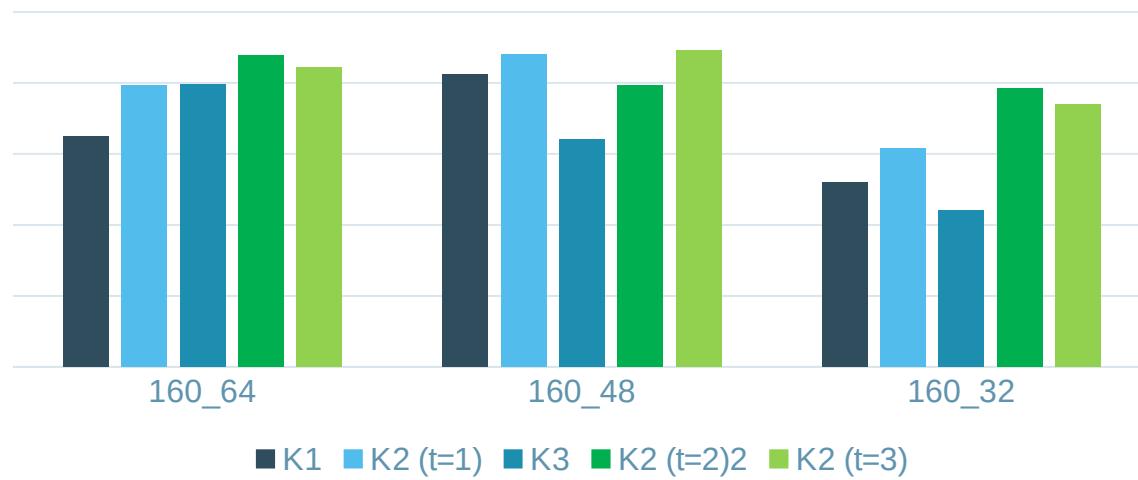


Results

$$\begin{array}{c} k_1 \quad k_2 \quad k_3 \quad k^t \\ \begin{array}{|c|c|} \hline 0 & -1 \\ \hline -1 & 0 \\ \hline \end{array} \quad \begin{array}{|c|c|} \hline 0 & 1 \\ \hline -1 & 0 \\ \hline \end{array} \quad \begin{array}{|c|c|} \hline 0 & -1 \\ \hline -2 & -3 \\ \hline \end{array} \quad \begin{array}{|c|c|} \hline 0 & t \\ \hline -t & 0 \\ \hline \end{array} \\ \hline \end{array}$$



PRIVATE

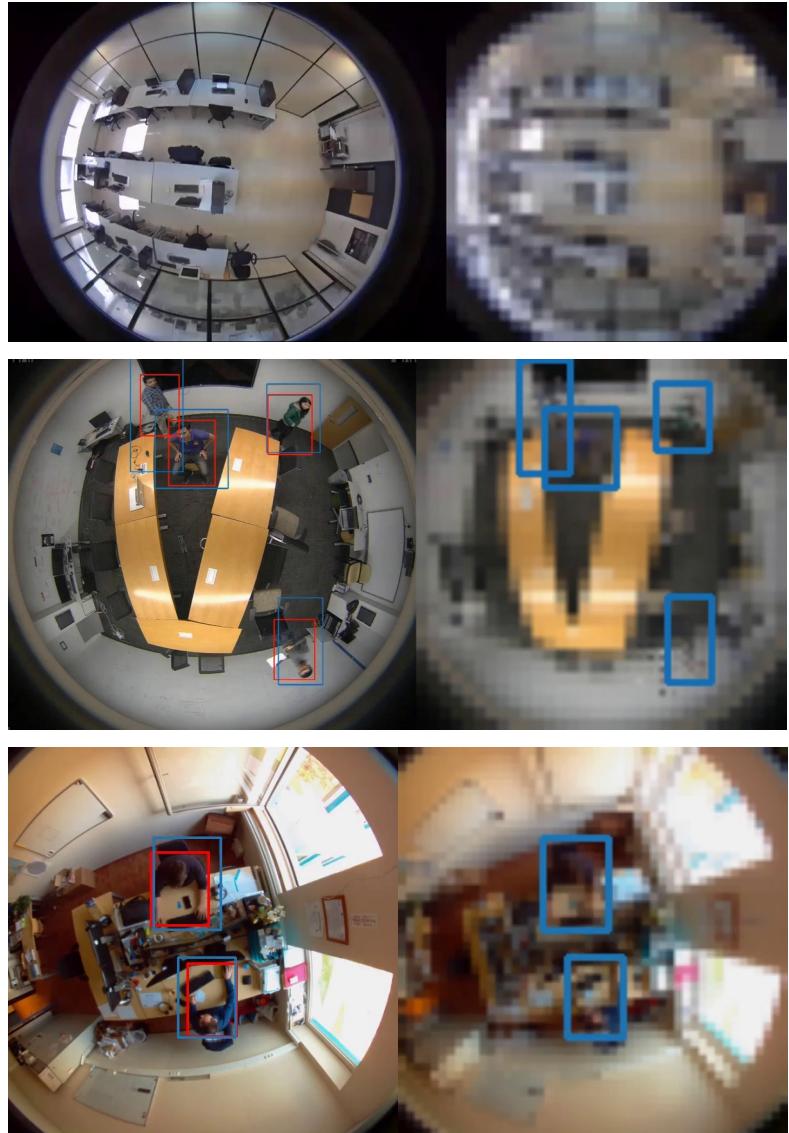


Conclusion

- Training possible with automatically generated annotations
- Can run on embedded hardware
- Already good performance
- Image resolution of 32 pixels

Future Work

- Improving label generation
- Influence of large room changes?
- What when the room gets bigger?



Thank you for your attention!
Questions?

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