SAGIVTECH

IMVC 2024

Polarimetric Imaging for Perception

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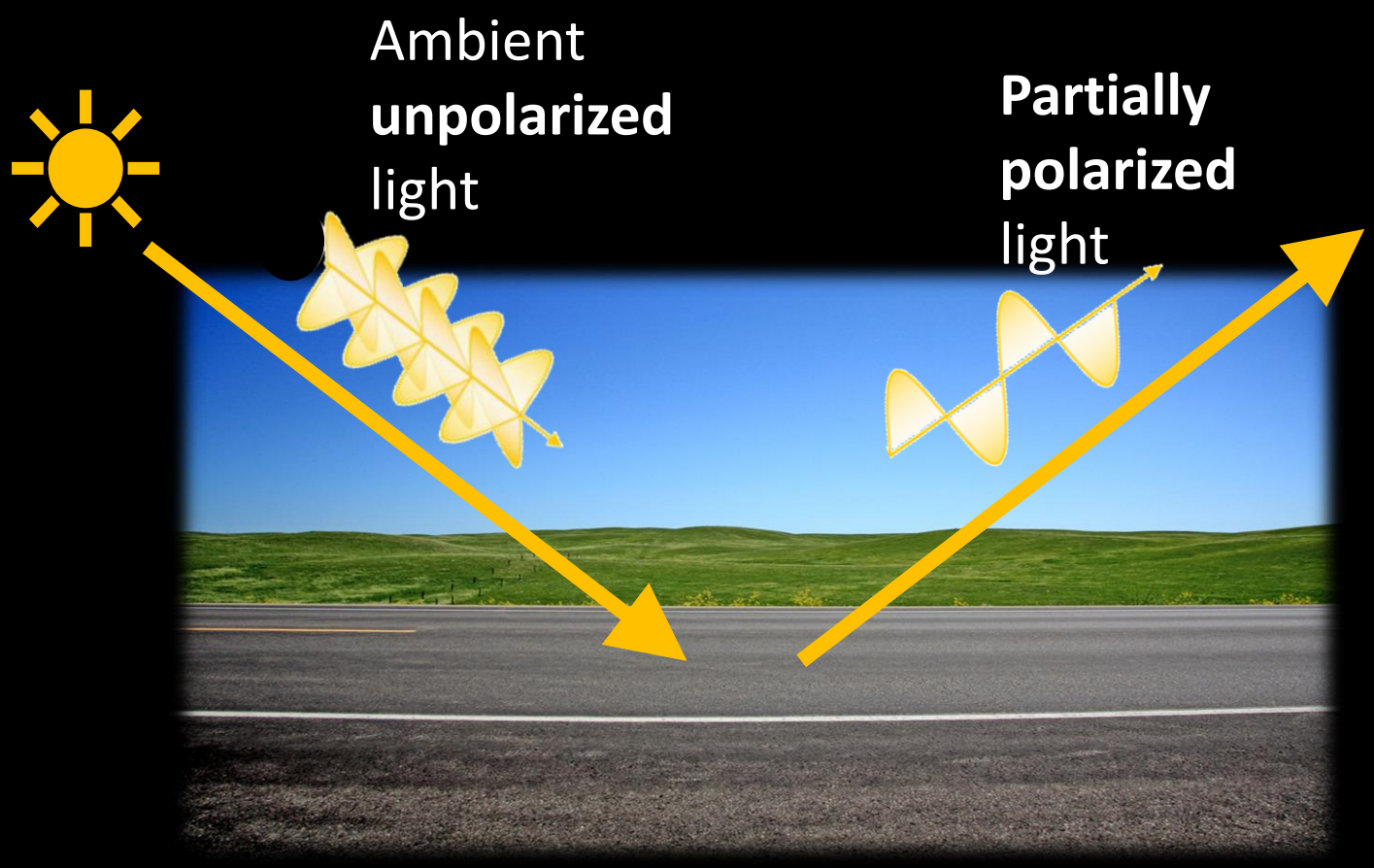
General Motors

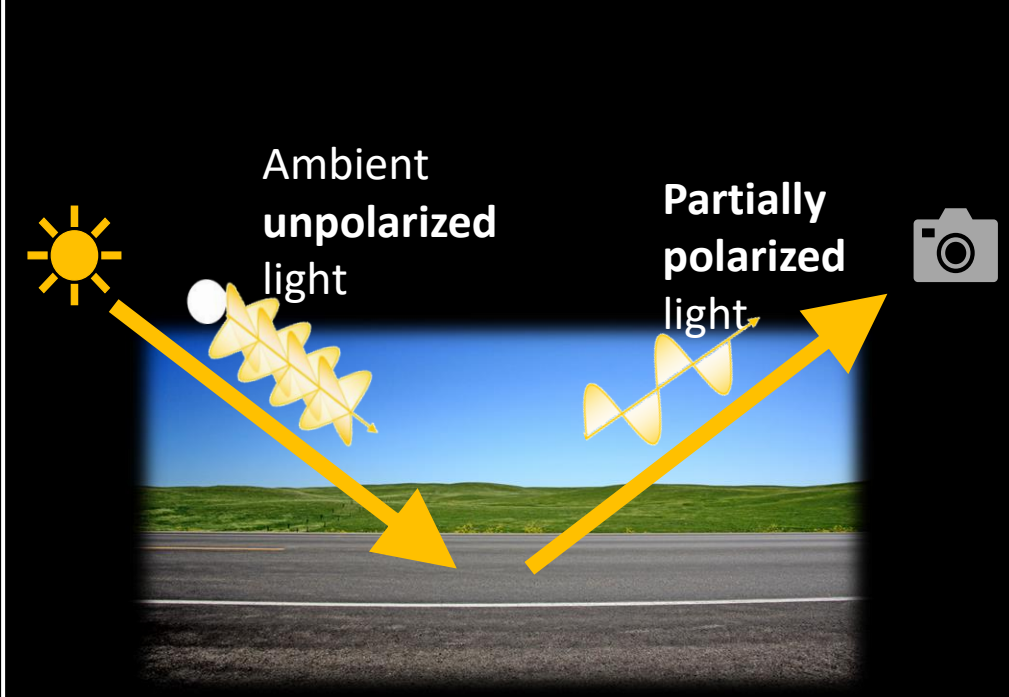
Polarization of Light

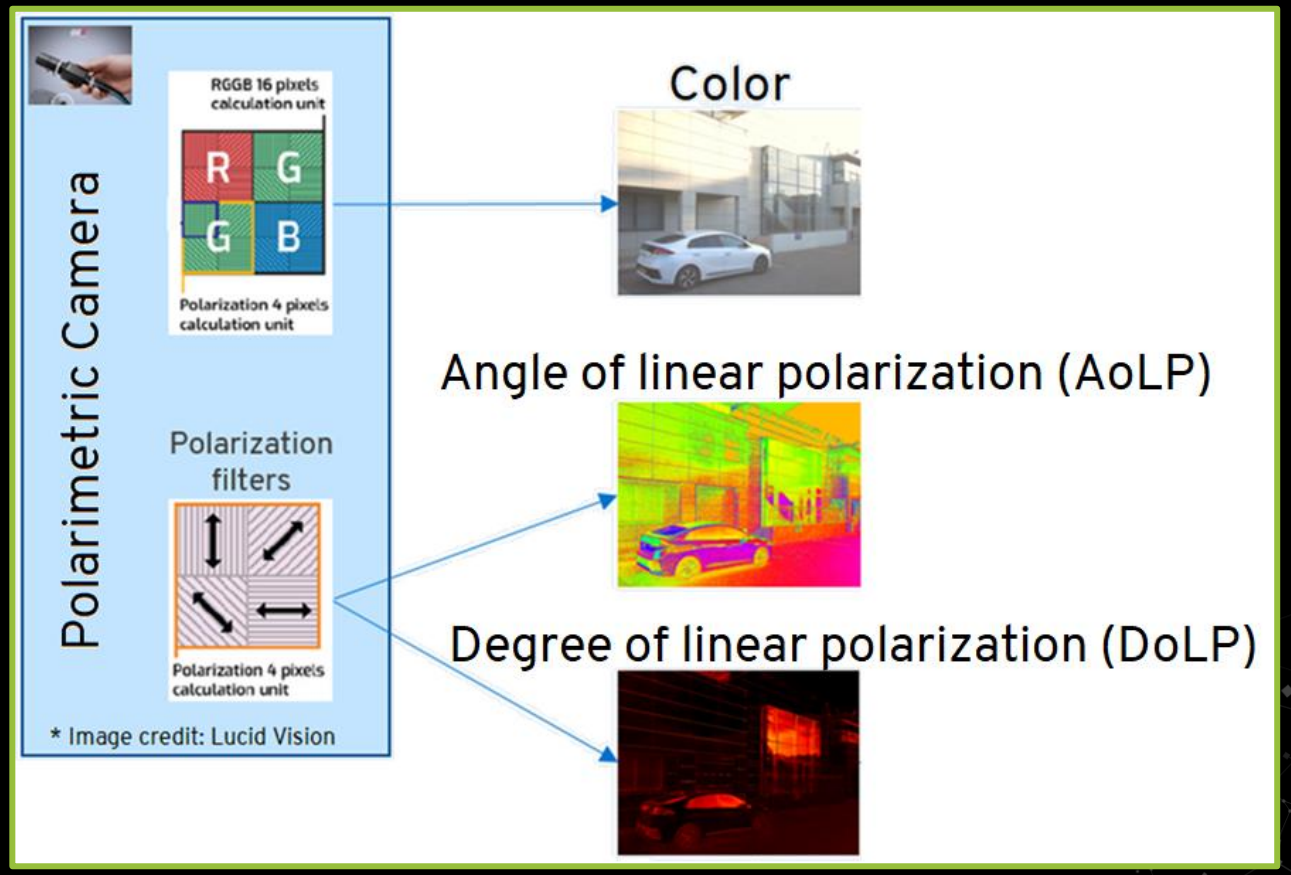


Polarization State

- Surface orientation
- Material properties
- Viewing direction

Polarization of Light

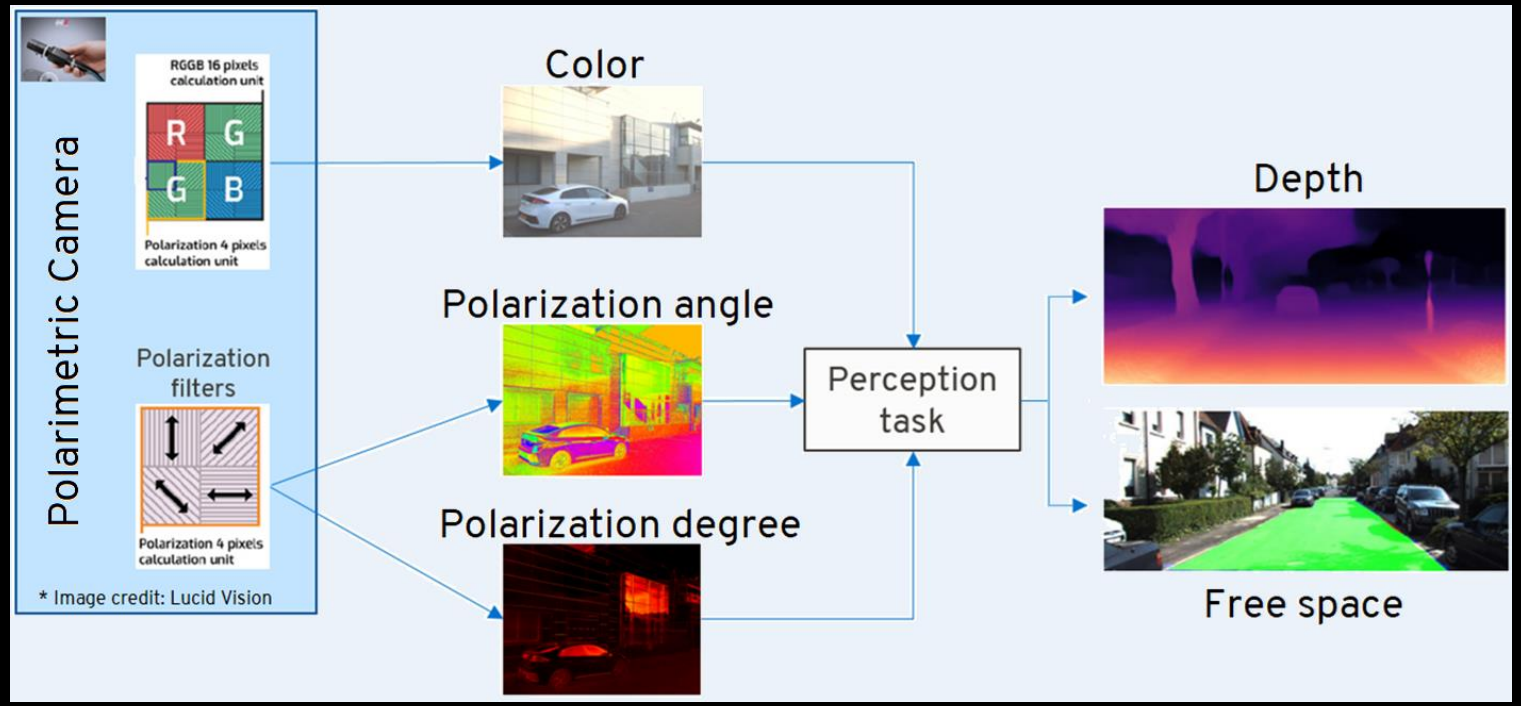




RGB-polarimetric (RGBP) camera

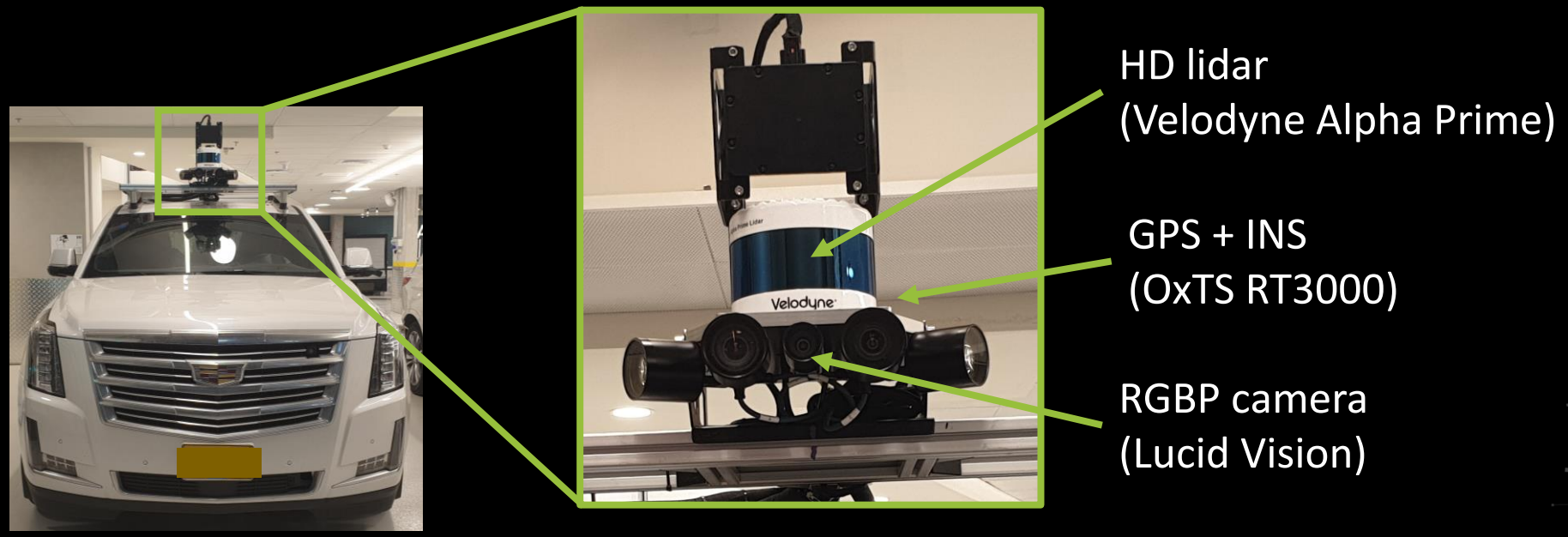
Polarimetric Imaging for Perception

Goal: Explore the potential improvement of perception tasks, when using an RGBP camera.



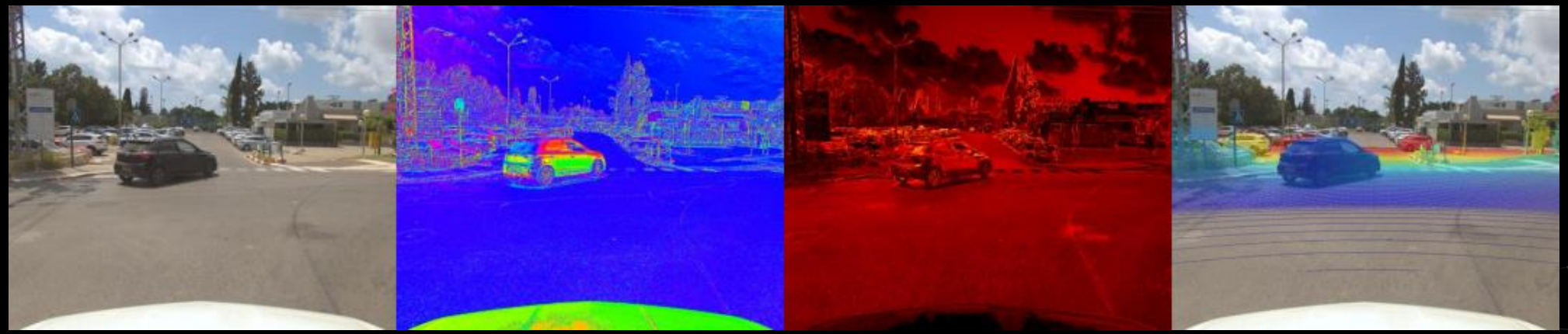
RGBP Dataset – Data Collection

- Setup built in-house.
- Full calibration: camera – lidar – [GPS + inertial system].



RGBP Dataset

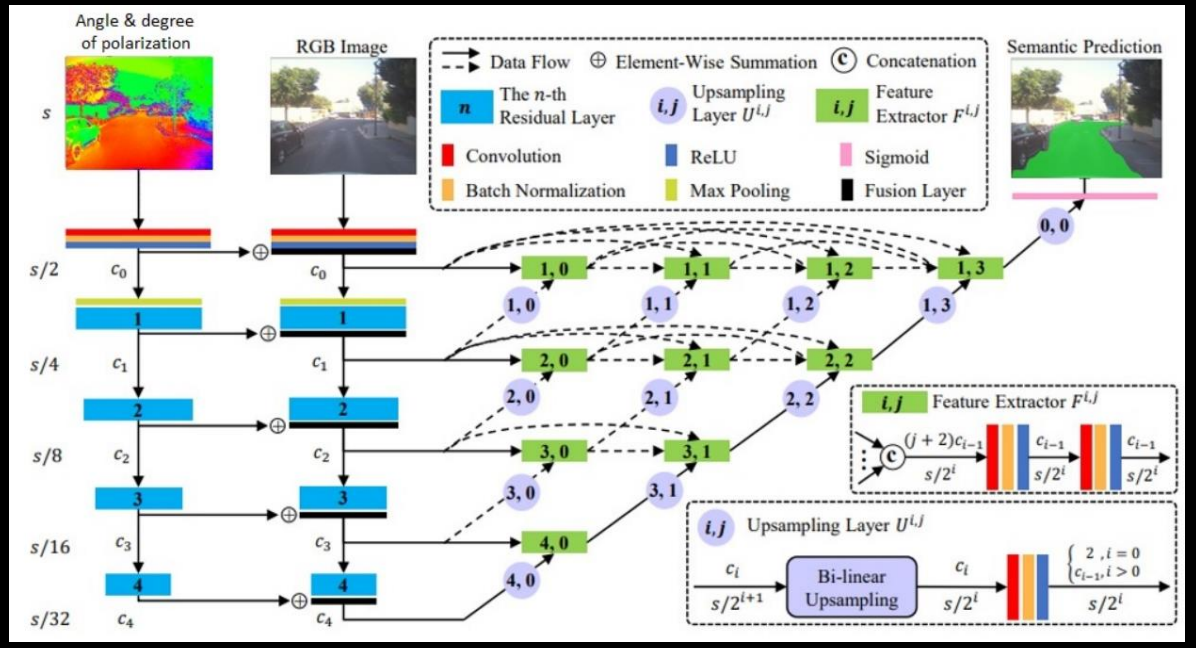
- 12K samples: RGB, AoLP, DoLP, lidar and pose.
- 8K images with free space annotated.
- Noon-time to avoid heading dependency.



RGB AoLP DoLP Lidar

Free Space Estimation

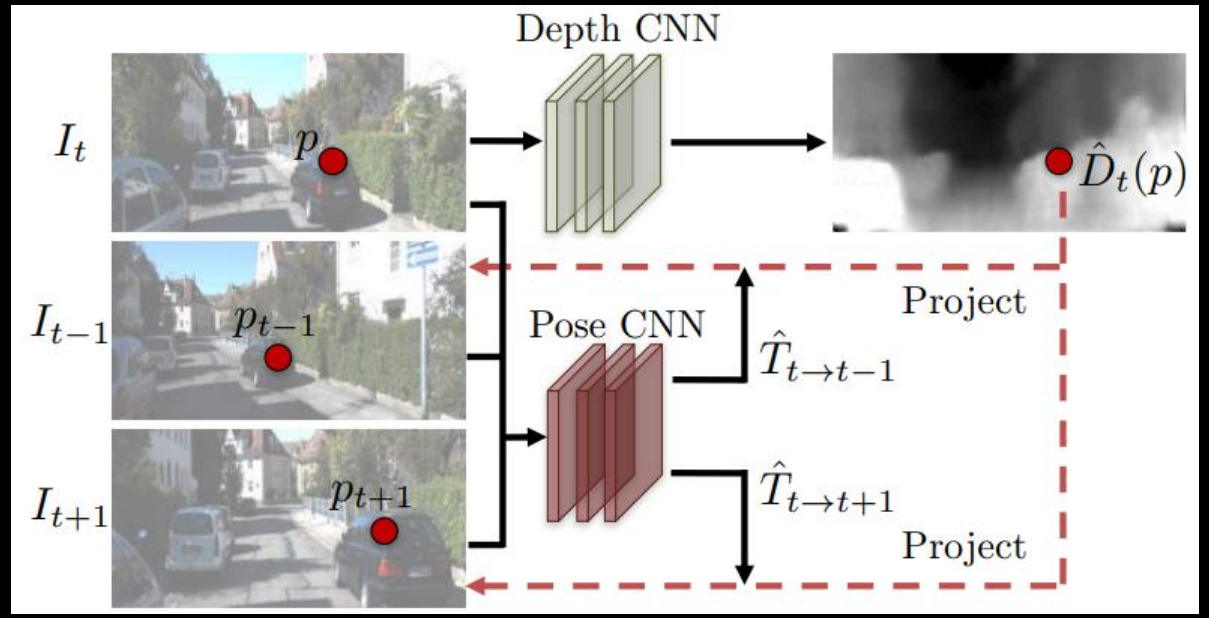
- Adapted SNE-RoadSeg network [1]. Removed normals estimation.
- Polarization features added: $[\sin(2 \cdot AoLP), cos(2 \cdot AoLP), 2 \cdot DoLP - 1]$.



[1] Fan, Rui, et al. "Sne-roadseg: Incorporating surface normal information into semantic segmentation for accurate freespace detection." ECCV, 2020.

Depth Estimation

- Adapted self-supervised monodepth v2 [2].
- Polarization features added: $[\sin(2 \cdot AoLP), cos(2 \cdot AoLP), 2 \cdot DoLP - 1]$.



[2] Godard, Clément, et al. "Digging into self-supervised monocular depth estimation." ICCV, 2019.

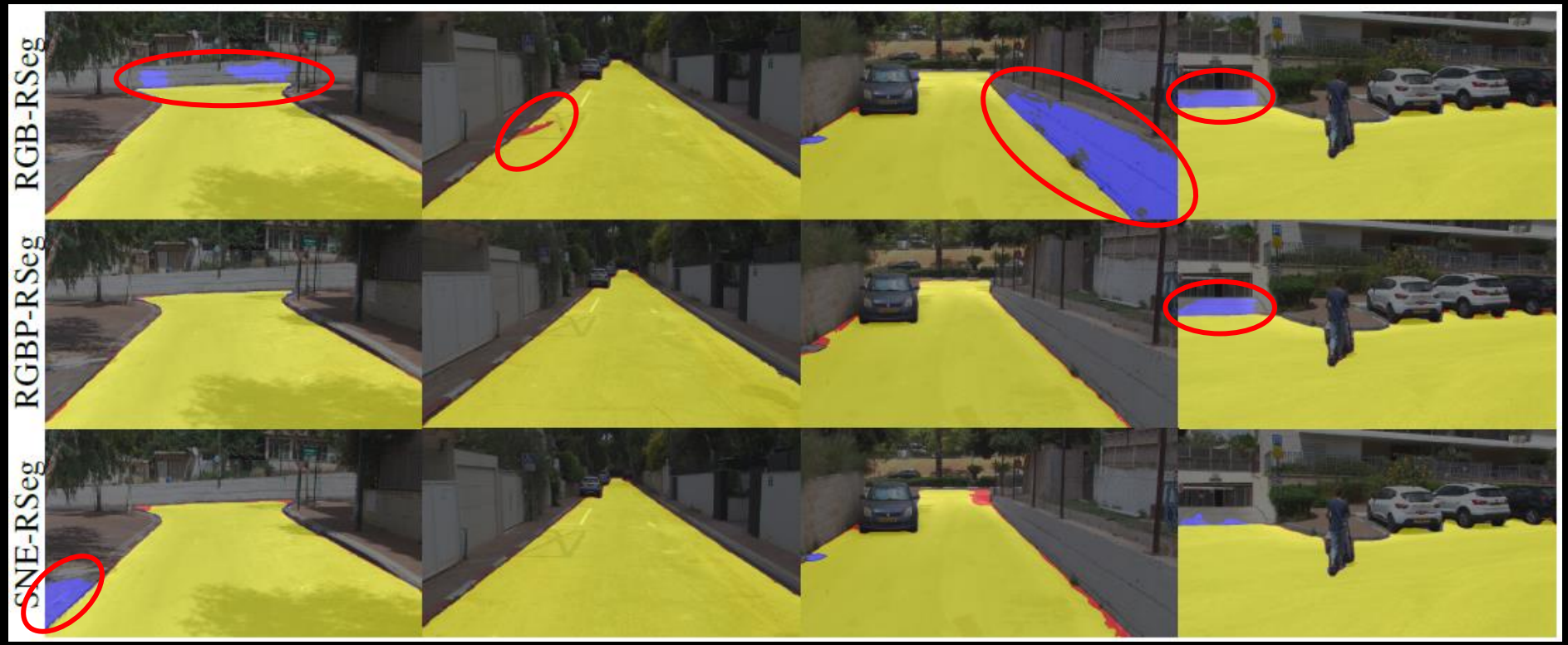
Results – Free Space

RGBP outperformed RGB.

Method	Accuracy	Precision	Recall	F_{max}	IoU	AP
RGB-RoadSeg	0.979	0.949	0.968	0.953	0.902	0.974
P-RoadSeg	0.865	0.845	0.534	0.641	0.467	0.634
RGBP-RoadSeg	**0.986**	**0.966**	**0.972**	**0.968**	**0.939**	**0.994**
SNE-RoadSeg	0.985	0.967	0.967	0.965	0.934	0.993

Results – Free Space

RGBP outperformed RGB.



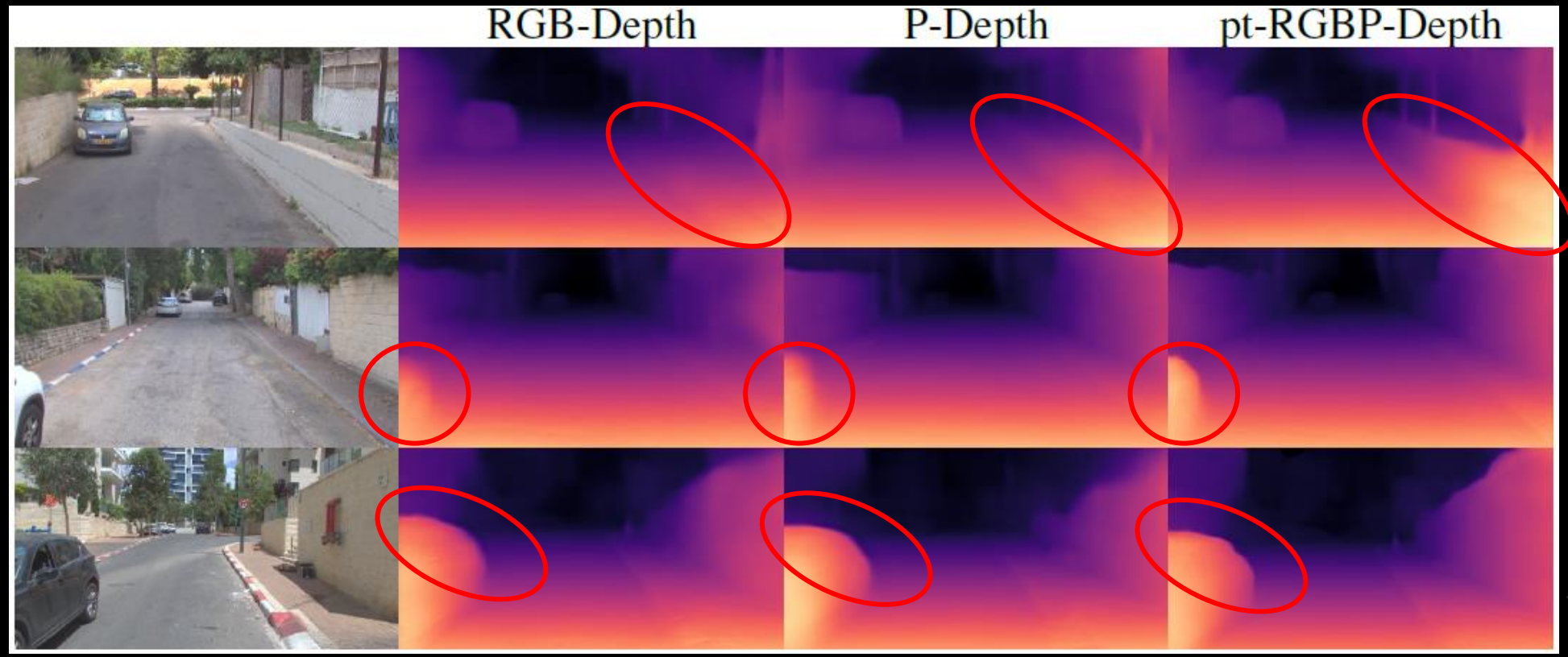
Results – Depth Estimation

RGBP and RGBP pre-trained on RGB (pt-RGBP) outperformed RGB.

Method	Error metric ↓				Accuracy metric ↑		
	Abs Rel	Sq Rel	RMSE	RMSE Log	$\delta < 1.25$	$\delta < 1.25^2$	$\delta < 1.25^3$
RGB-Depth	0.094	0.838	6.389	0.166	0.904	0.964	0.984
P-Depth	0.091	0.811	6.325	0.164	0.907	0.966	0.985
RGBP-Depth	0.089	0.770	6.172	0.161	0.911	**0.968**	**0.986**
pt-RGBP-Depth	**0.086**	**0.767**	**6.109**	**0.158**	**0.915**	**0.968**	0.985

Results – Depth Estimation

RGBP and RGBP pre-trained on RGB (pt-RGBP) outperformed RGB.

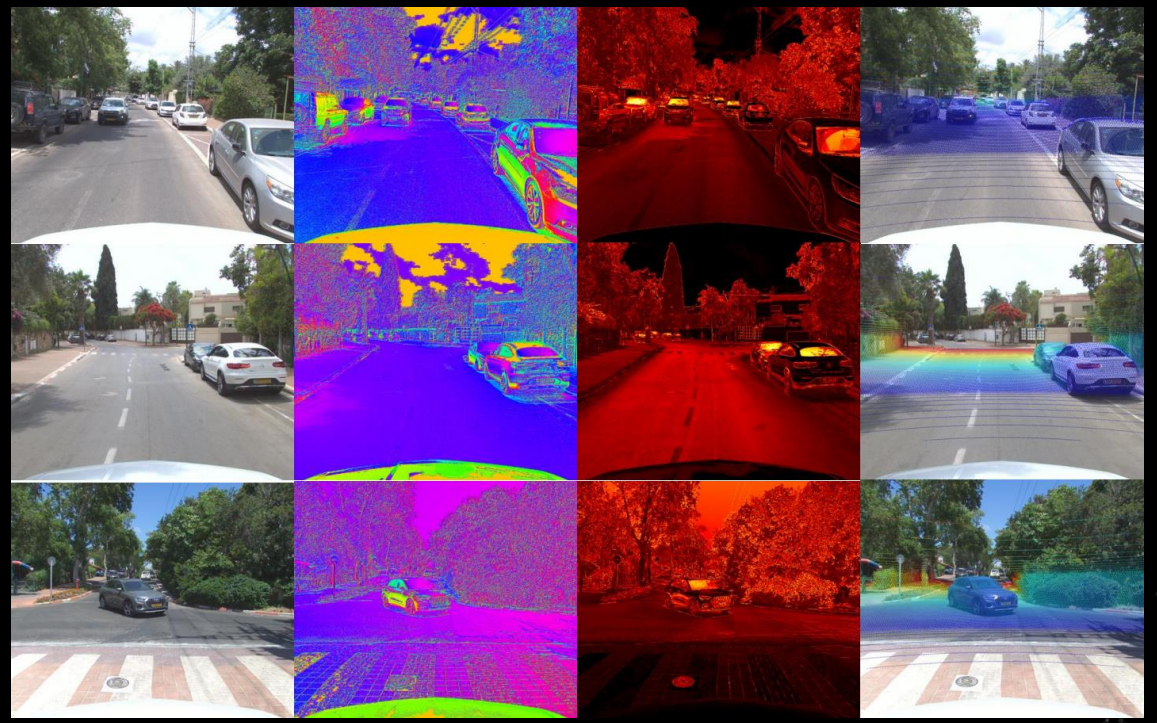


Conclusions

- New polarimetric dataset released for perception tasks.
- Polarization data improved free space and depth estimation systems.
- Minimal architectural changes needed for quantitative improvement.

Thanks!

Download the dataset!



RGB AoLP DoLP Lidar

https://michaelbaltaxe.github.io/polarimetric_perception