Gated Stereo:
Joint Depth Estimation from Gated and Wide-Baseline Active Stereo Cues

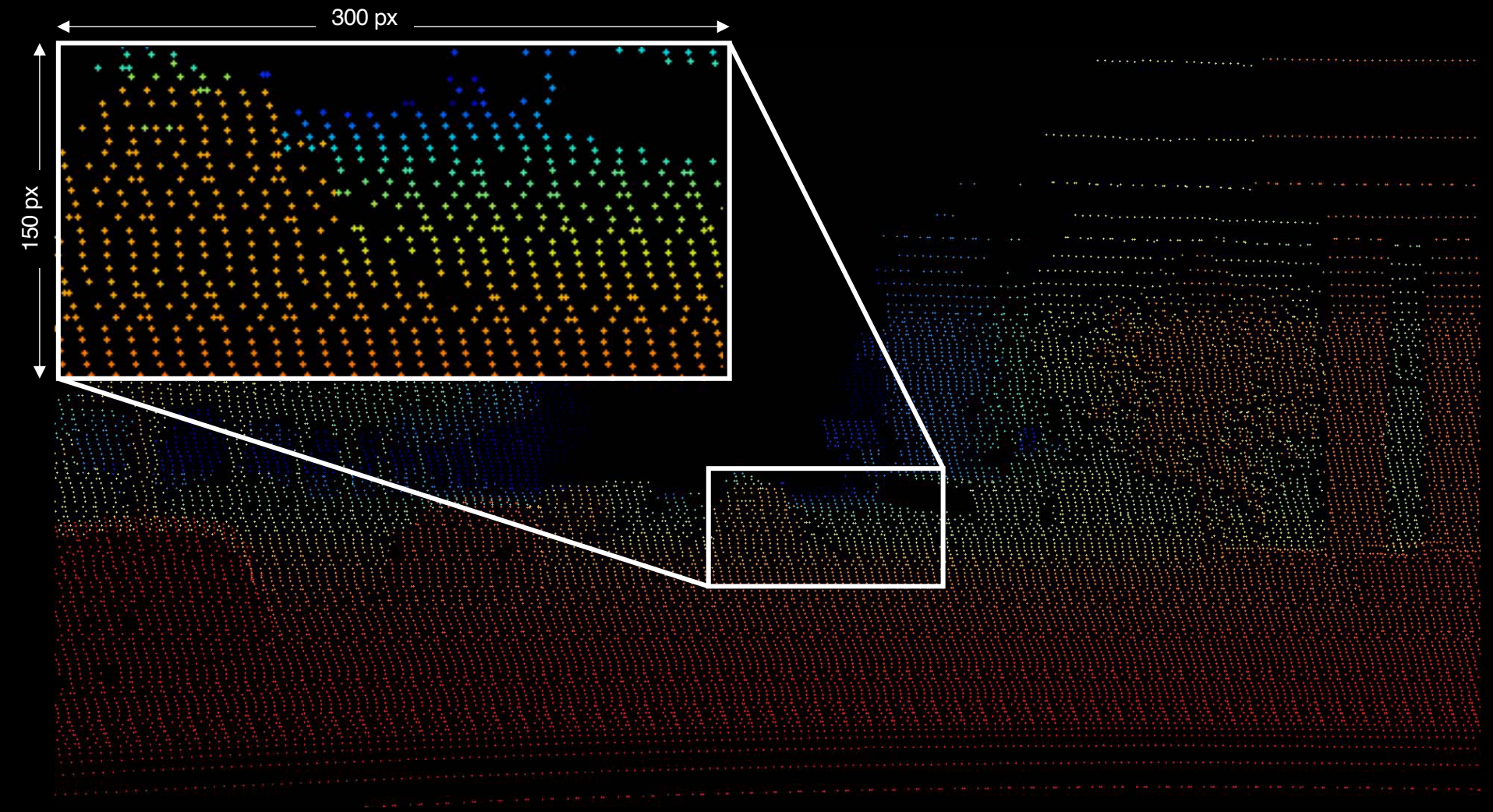
Stefanie Walz[1] Mario Bijelic[3] Andrea Ramazzina[1] Amanpreet Walia[2] Fahim Mannan[2] Felix Heide[2,3]

[1]*Mercedes-Benz AG*, [2]*Algolux*, [3]*Princeton University*

Data and code are available at
https://light.princeton.edu/publication/gatedstereo

Overview – Motivation

Scanning LiDAR



→ Scanning LiDAR systems provide accurate but sparse depth

Overview – Motivation

Scanning LiDAR

CMOS Array Sensor

→ CMOS sensor arrays provide dense output but are missing depth accuracy

Overview – Motivation

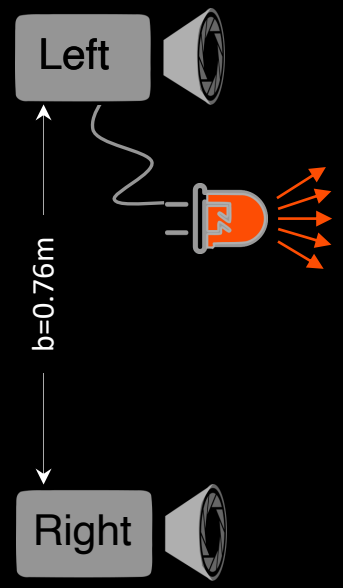
Scanning LiDAR

CMOS Array Sensor

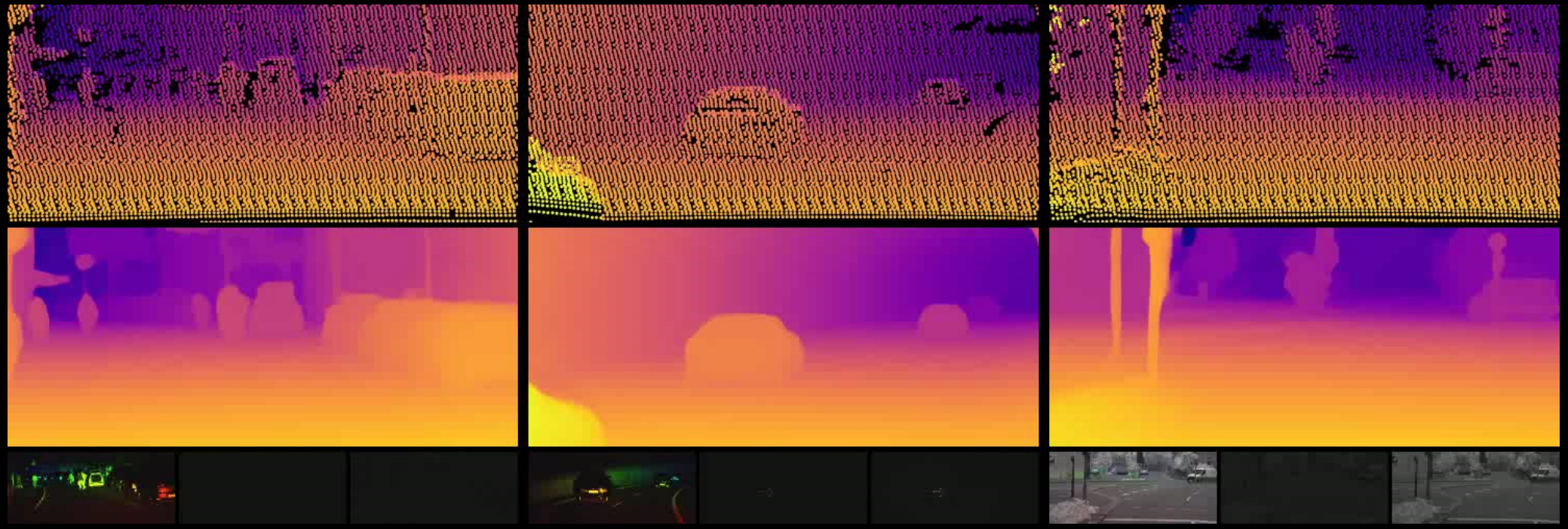
Gated System

→ Gated systems couple CMOS sensor to active illuminators

Overview – Gated Stereo



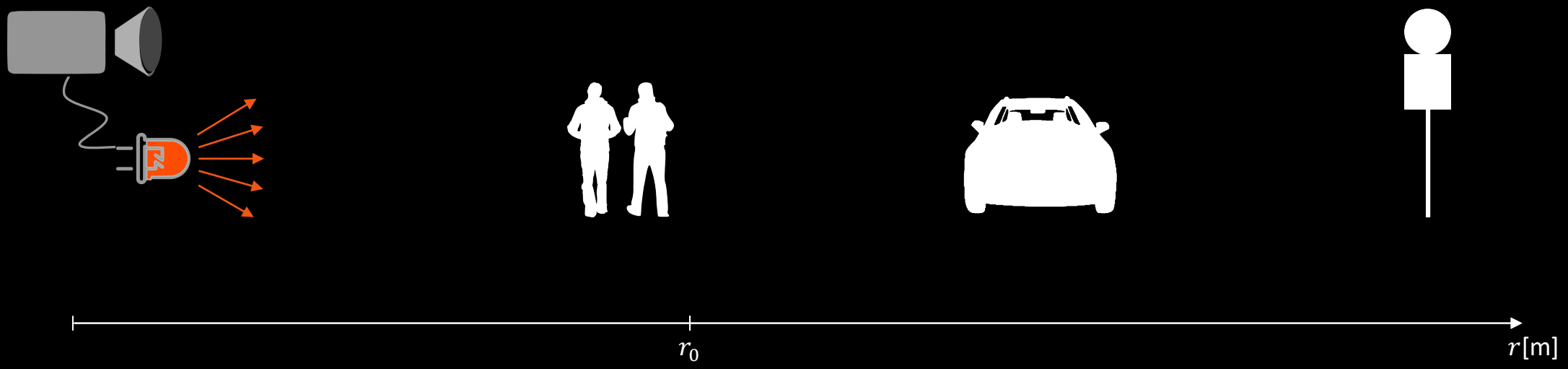
Overview – SOTA Comparison



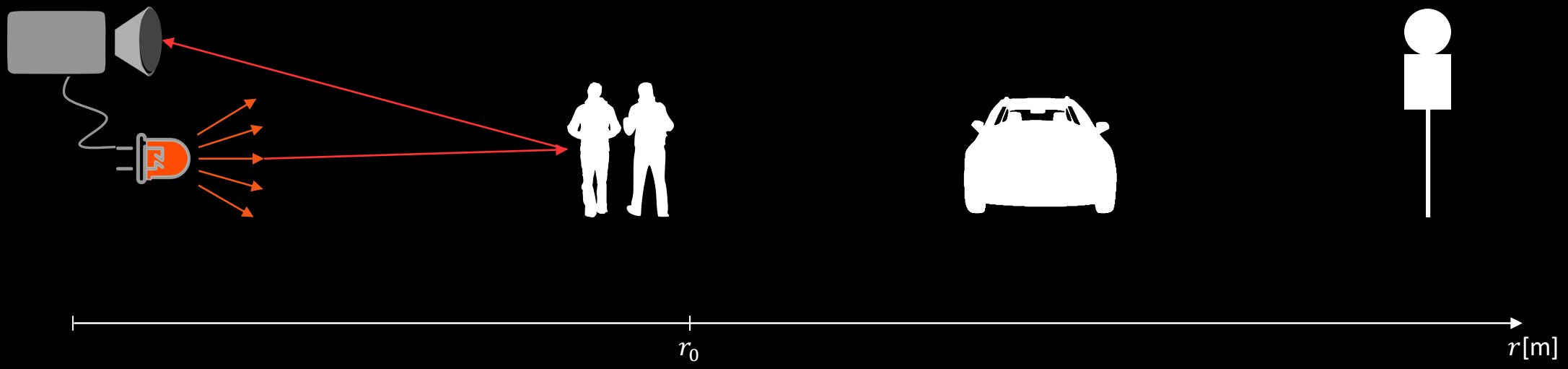
Key Contributions:

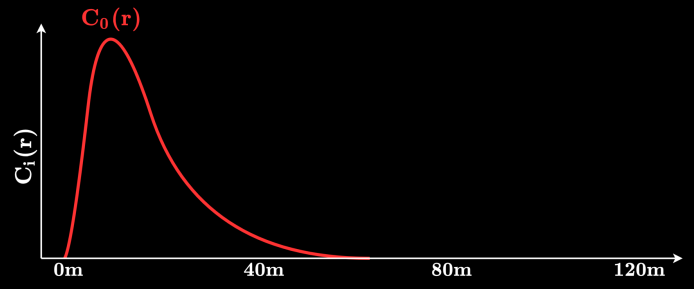
- Novel depth estimation approach for gated stereo images
- Providing first gated stereo dataset
- **Improvement of 50% MAE compared to next best RGB stereo method**

Gated Imaging



Gated Imaging

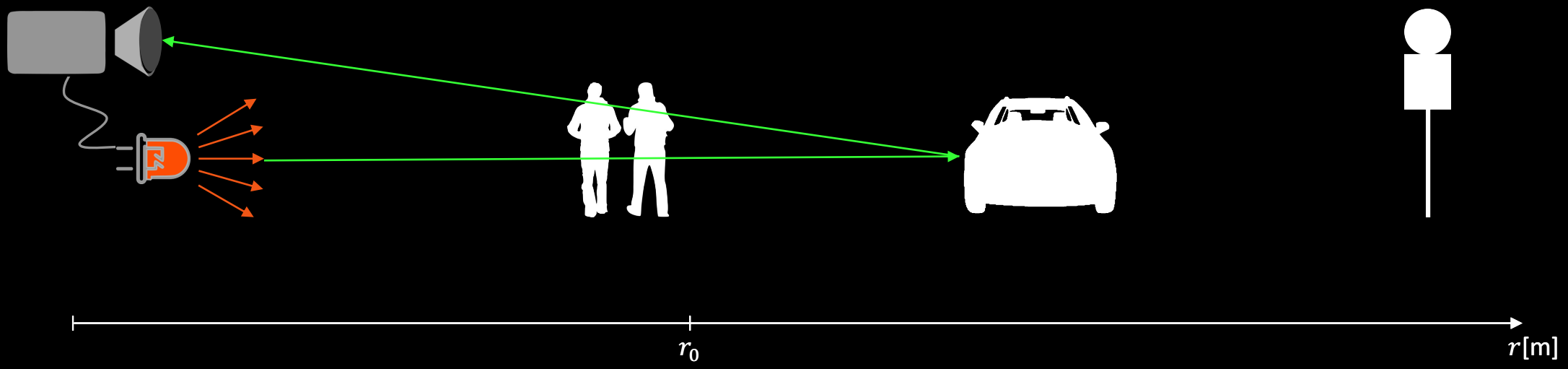


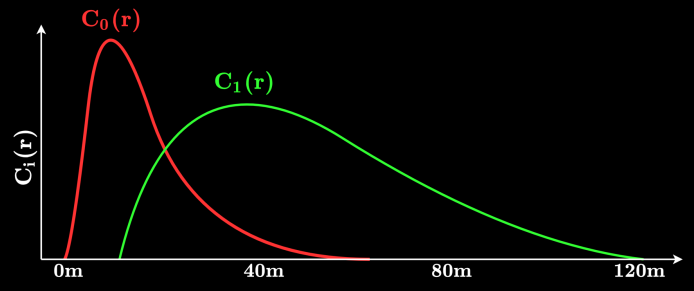


Intensity Profile

Slice 1

Gated Imaging



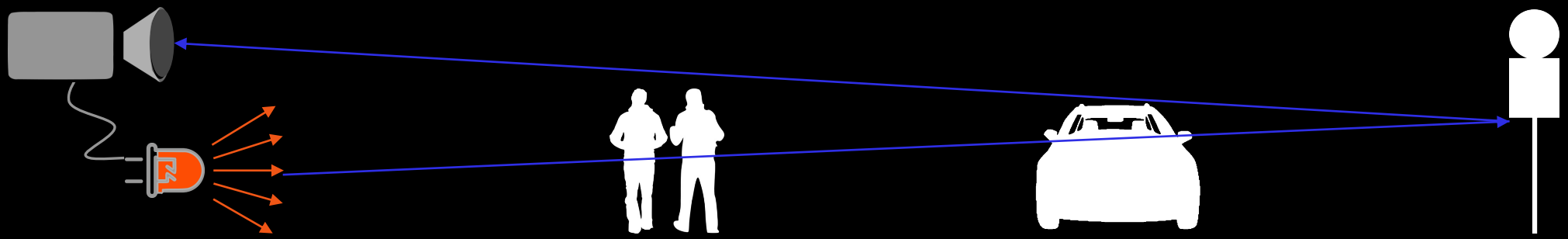


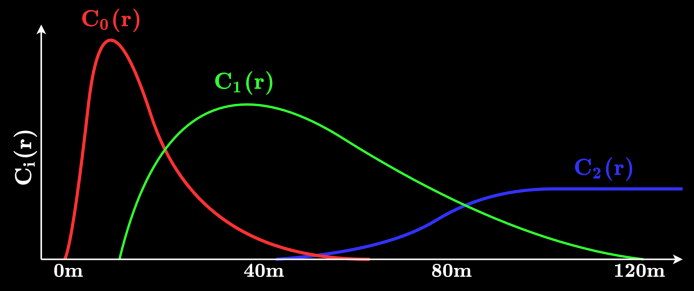
Intensity Profile

Slice 1

Slice 2

Gated Imaging





Intensity Profile

Slice 1

Slice 2

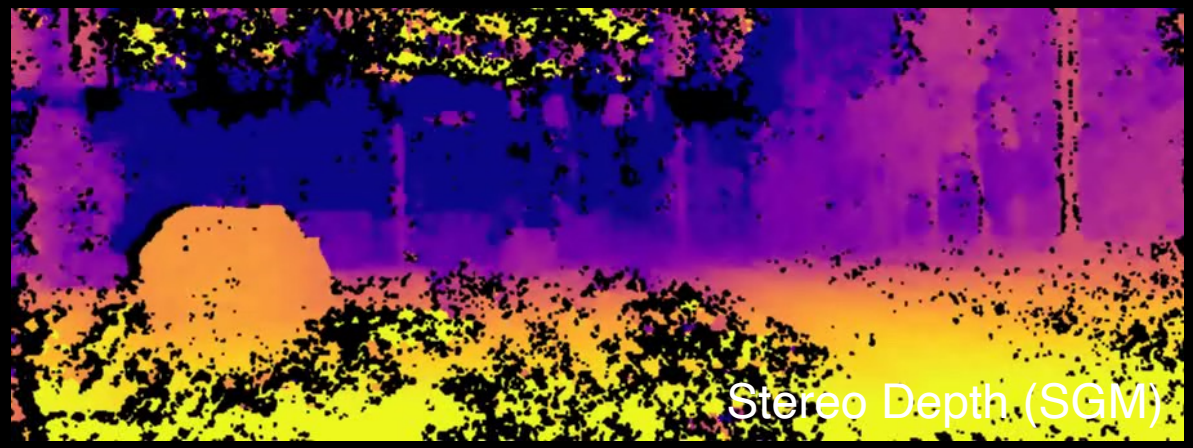
Slice 3

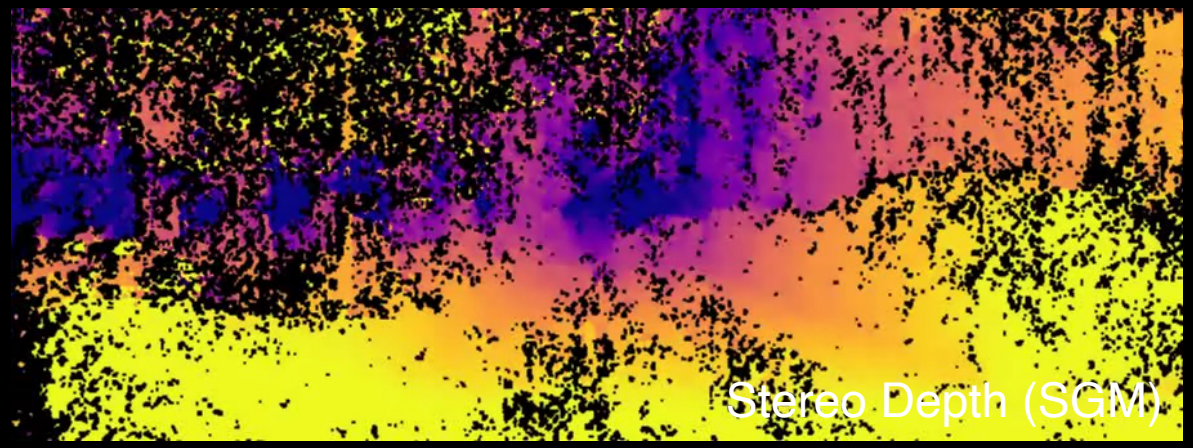
What about Depth from Stereo RGB Cameras?


→ Good Stereo Depth Cues




→ Reduced Stereo Correspondences

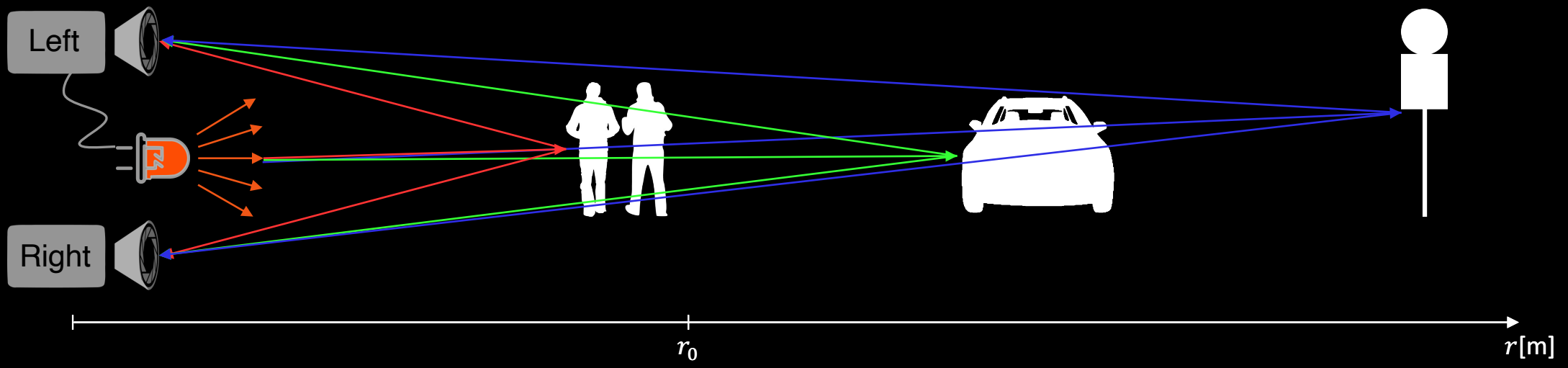


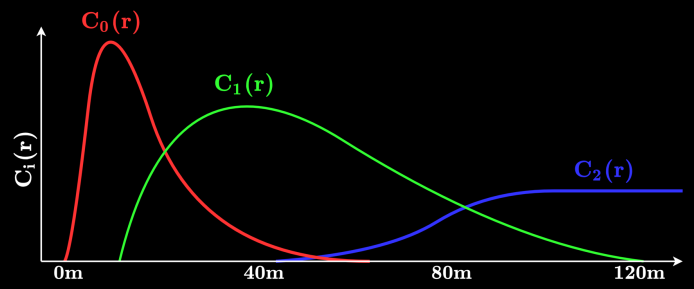


Daytime Conditions

Nighttime Conditions

Gated Stereo Imaging – Combining ToF with Multi-View Depth Cues





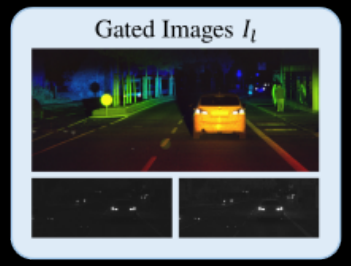
Intensity Profile

Slice 1

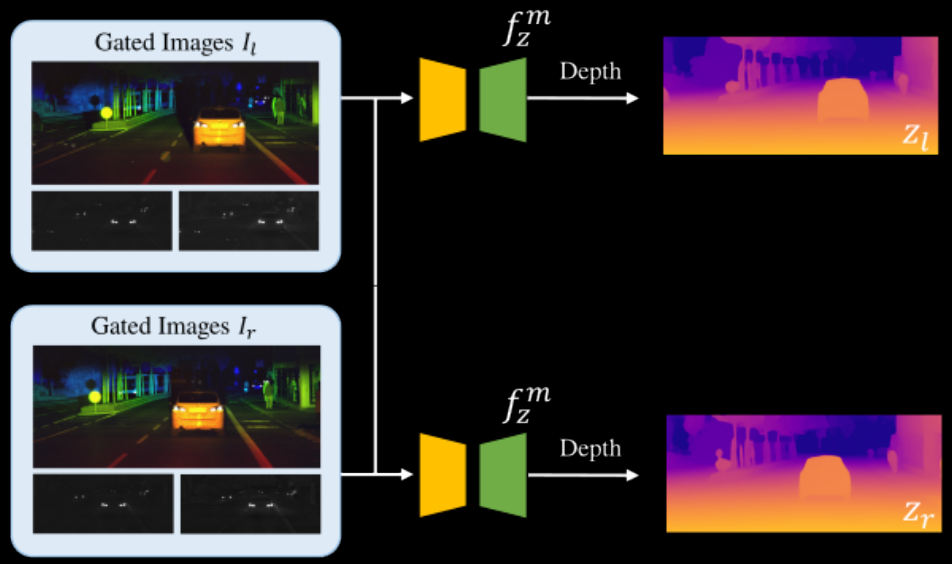
Slice 2

Slice 3

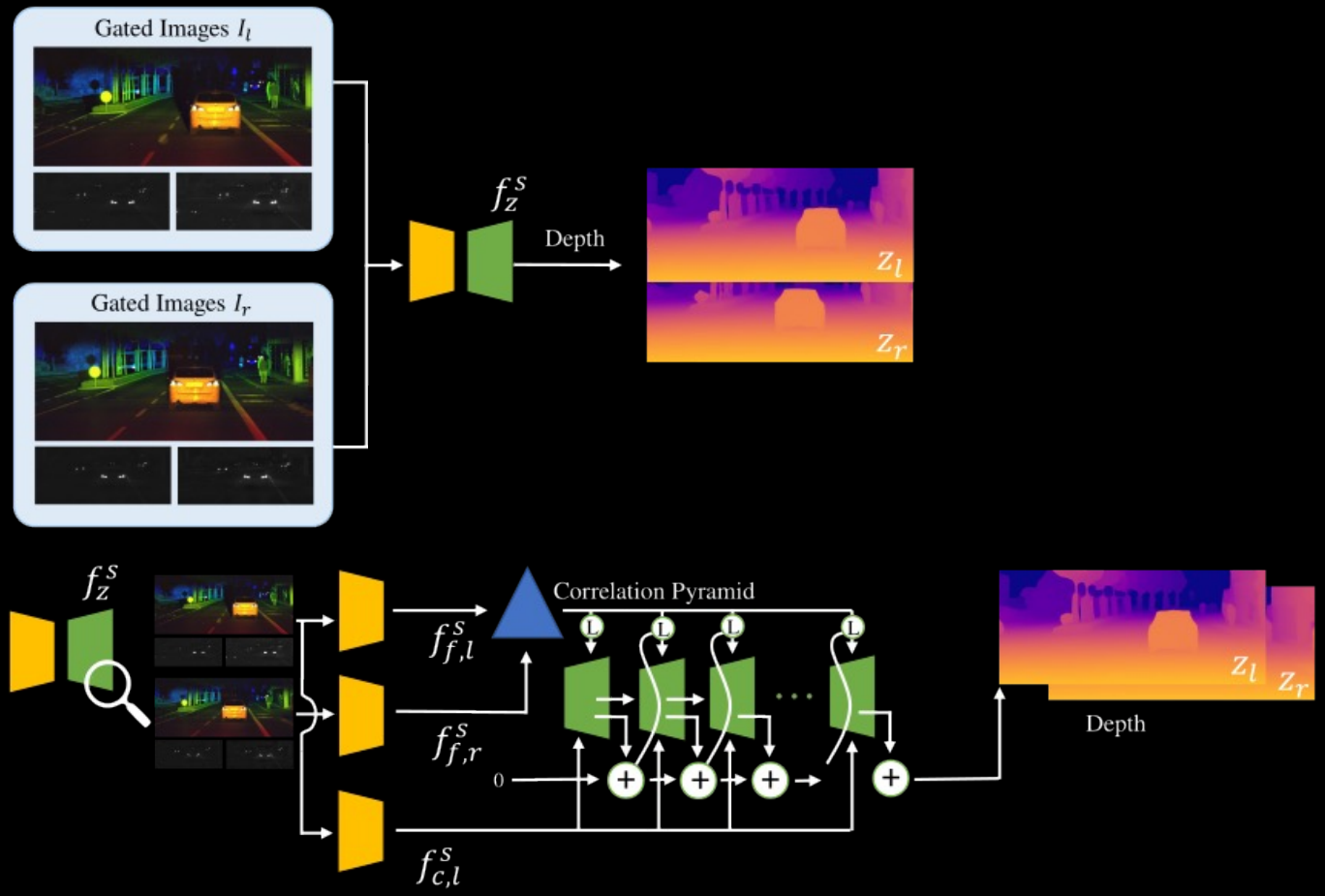
Gated Stereo – Input



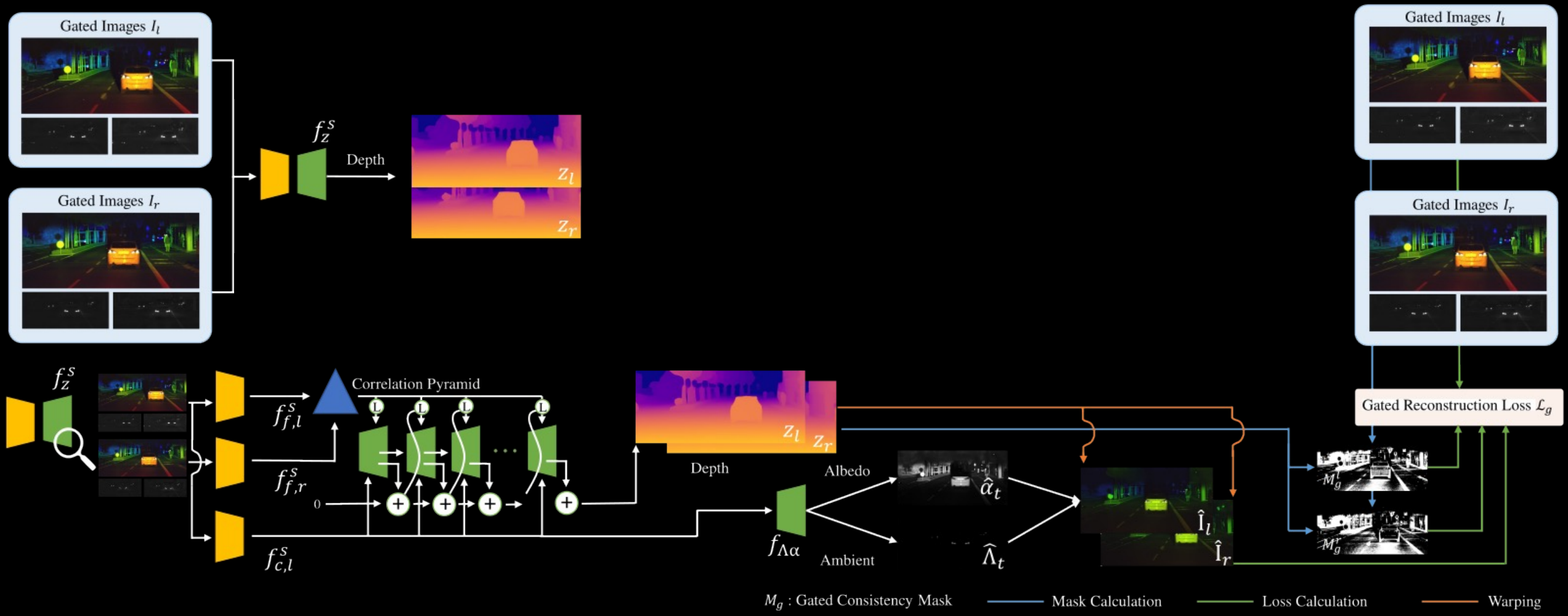
Gated Stereo – Monocular Branch



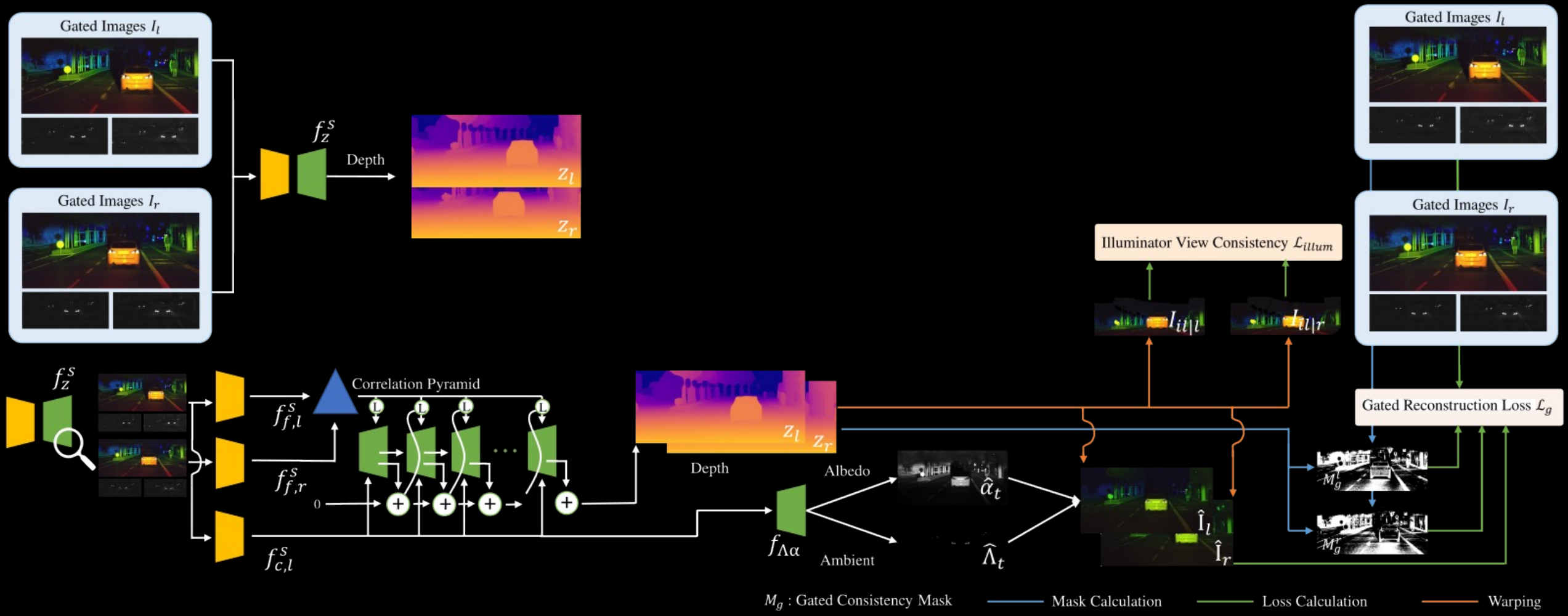
Gated Stereo – Stereo Branch



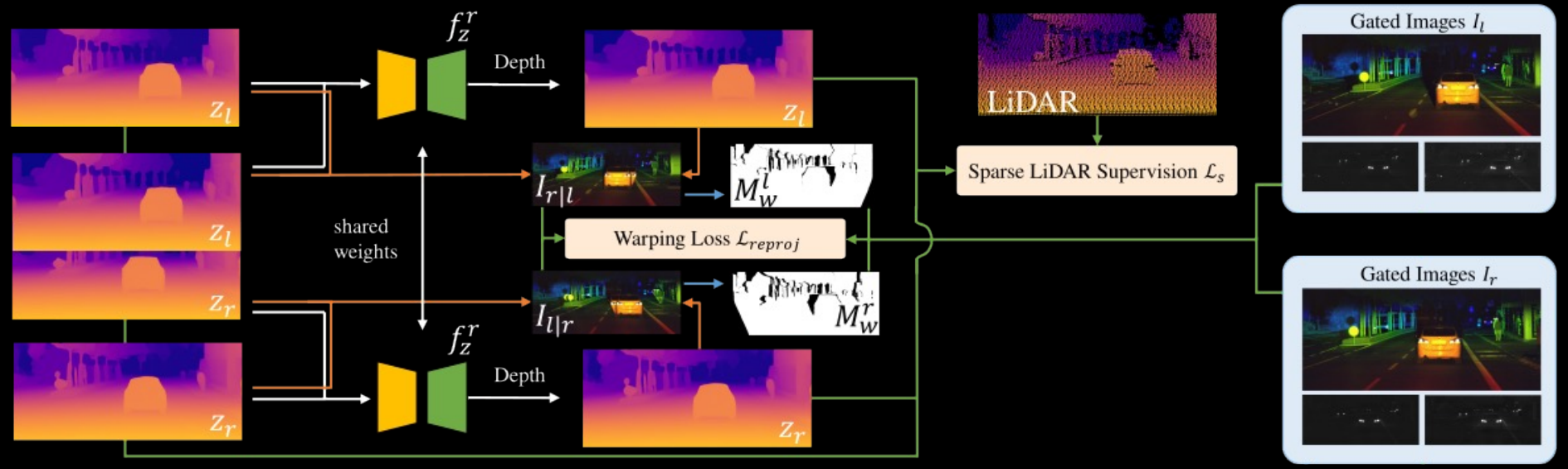
Gated Stereo – Gated Reconstruction Loss



Gated Stereo – Illuminator View Consistency



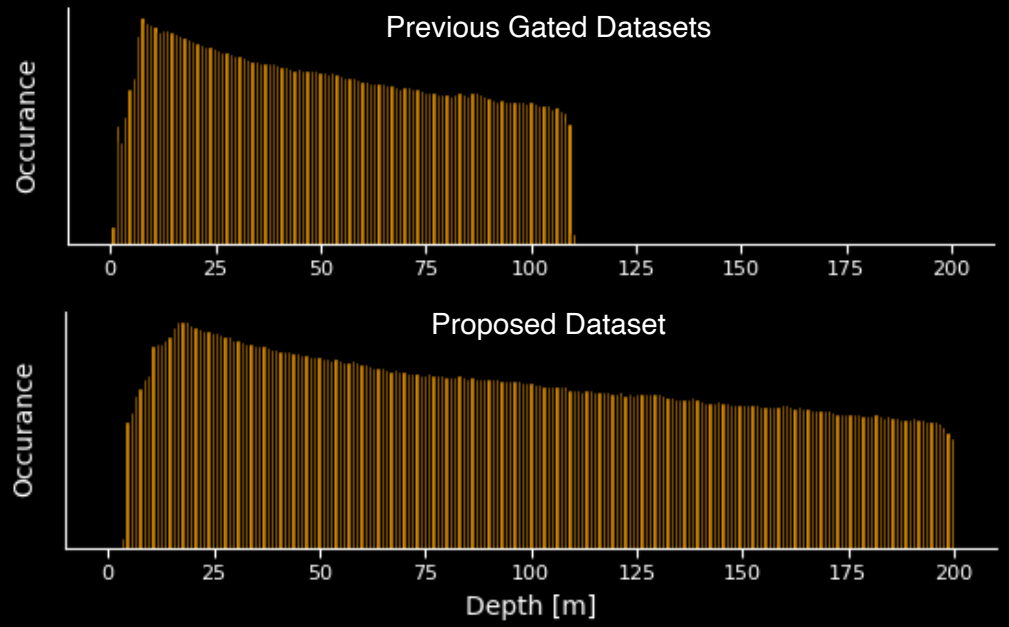
Gated Stereo – Fusion Network



M_w : Warping Visibility Mask M_g : Gated Consistency Mask Mask Calculation Loss Calculation Warping

Long-Range Stereo Dataset

Ground-Truth Depth Distribution:



Qualitative Results – Nighttime Downtown Environment

RGB

LiDAR

Gated Stereo

Gated2Gated

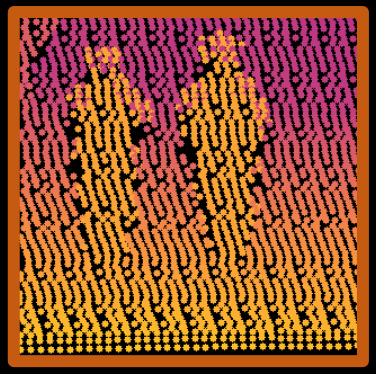
Sparse2Dense

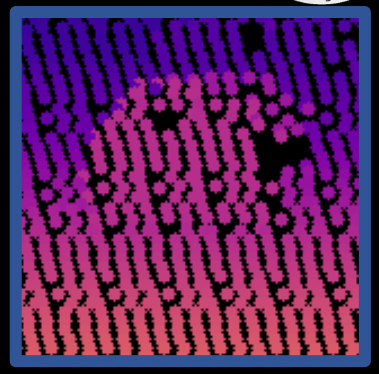
Stereo RGB

Qualitative Results – Nighttime Downtown Environment

RGB

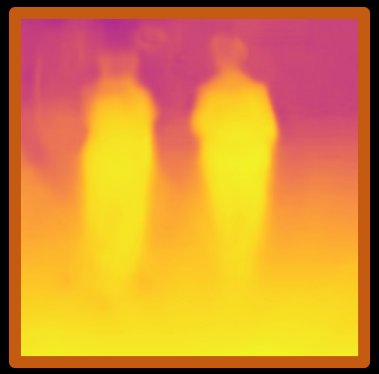
LiDAR

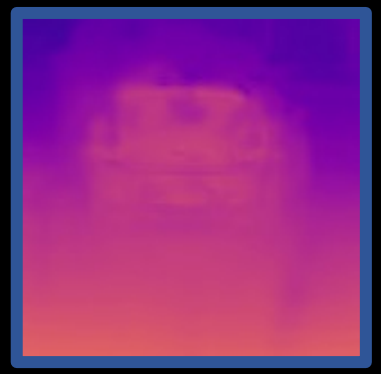




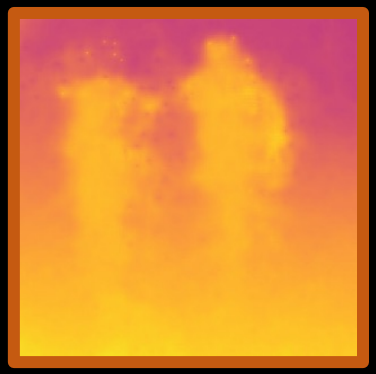
Gated Stereo

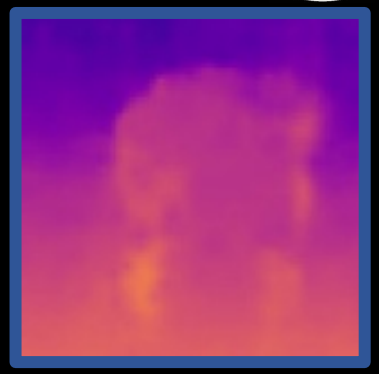
Gated2Gated



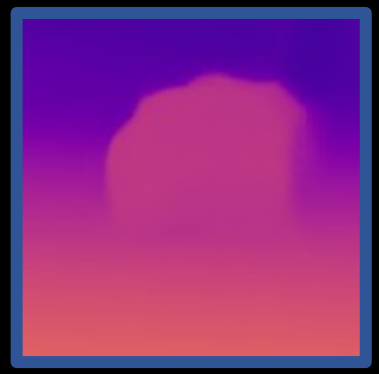


Sparse2Dense





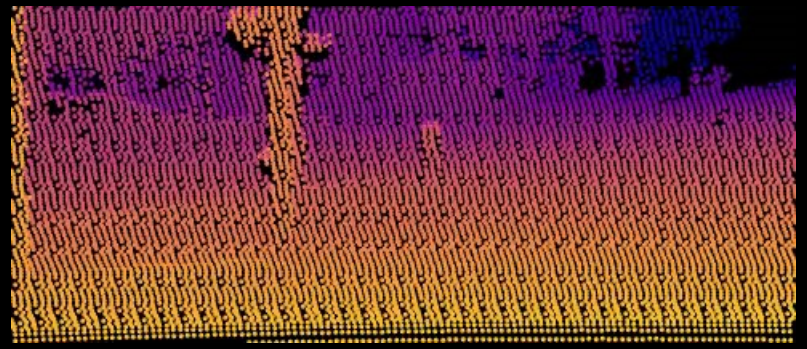
Stereo RGB



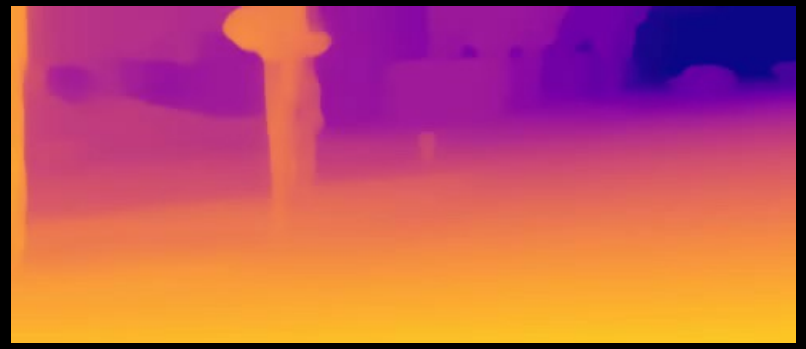
Qualitative Results – Nighttime Suburban Environment

RGB

LiDAR

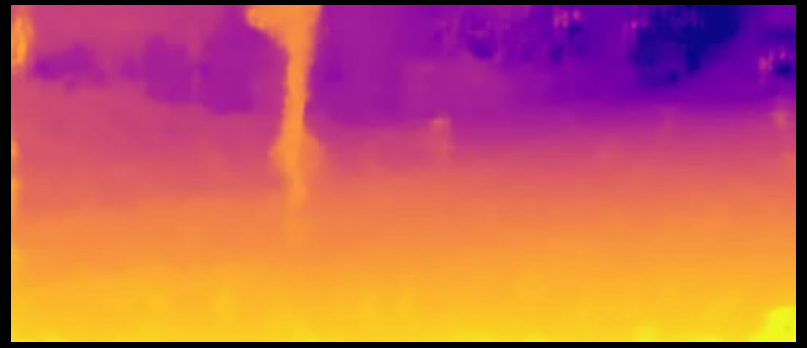


Gated Stereo



Gated2Gated

Sparse2Dense

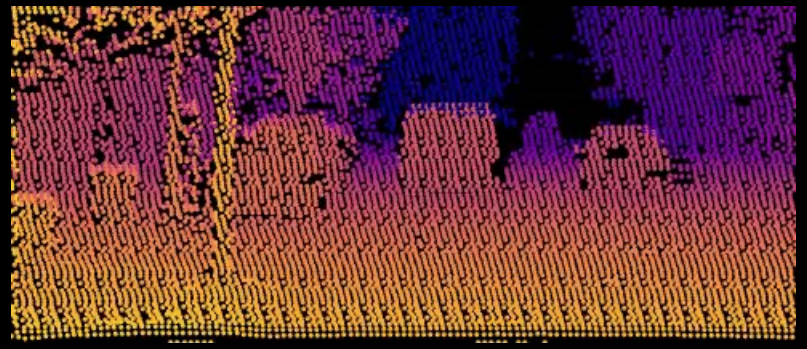


Stereo RGB

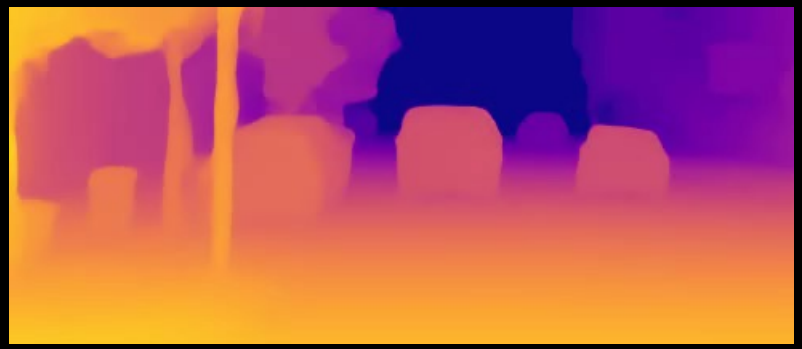
Qualitative Results – Daytime Downtown Environment

RGB

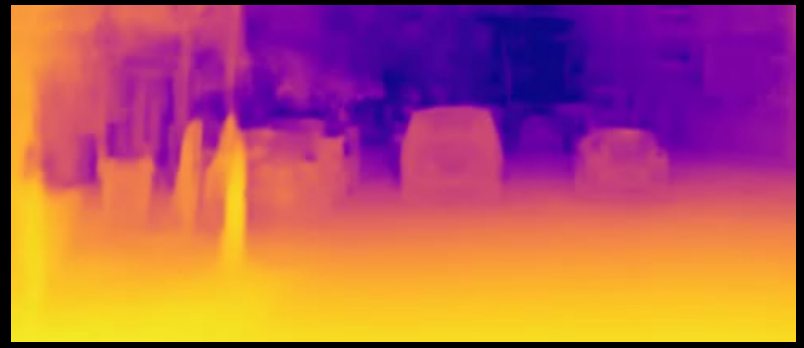
LiDAR



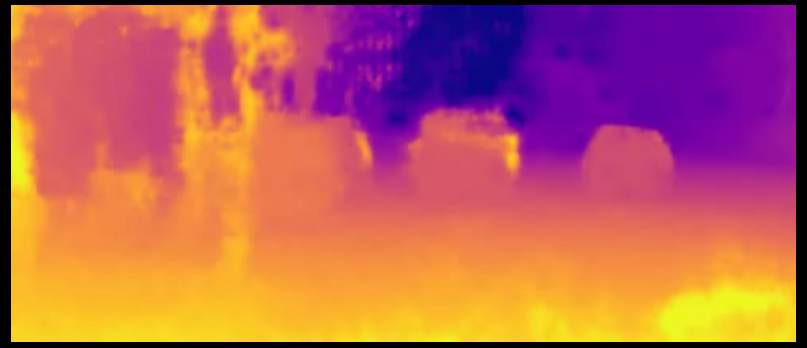
Gated Stereo



Gated2Gated



Sparse2Dense



Stereo RGB

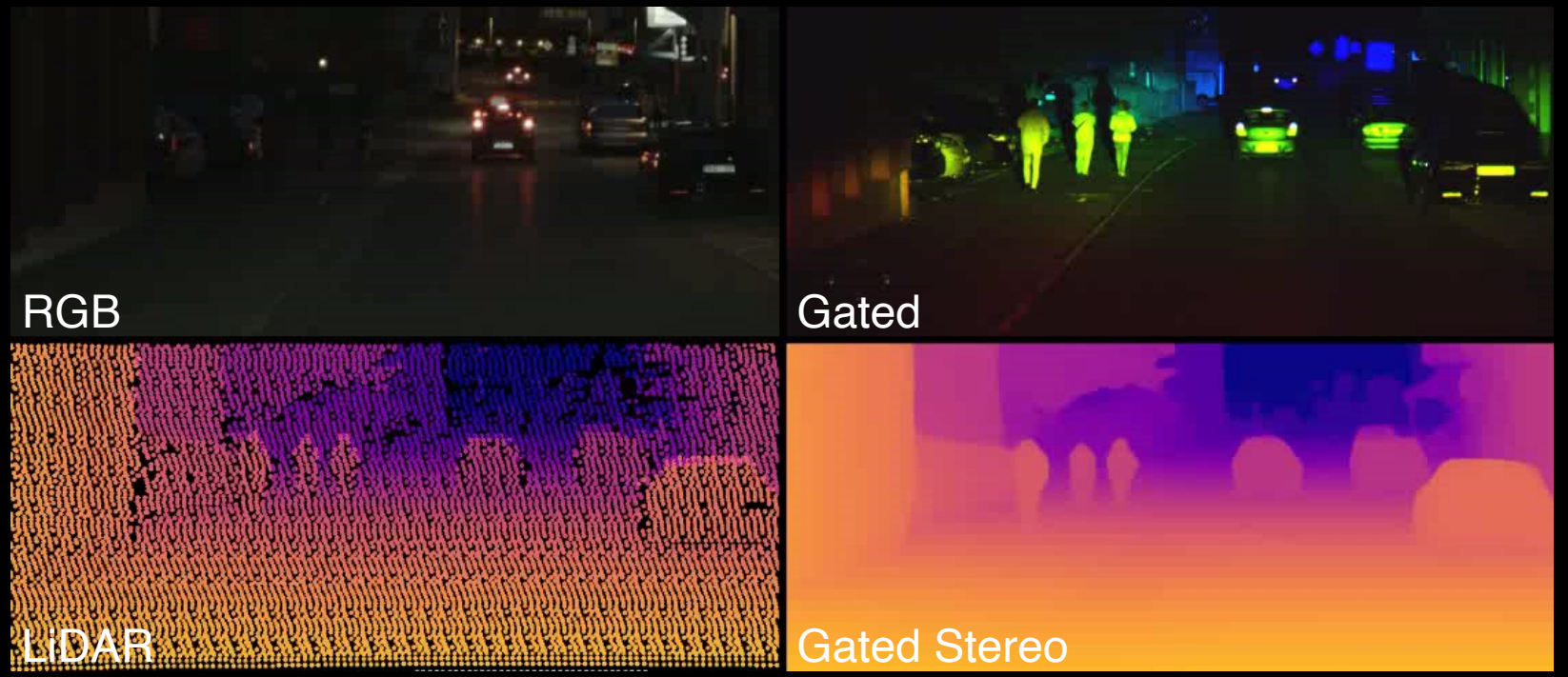
Comparison with SOTA Methods

Method	Modality	Train	Test Data - Night						Test Data - Day					
			RMSE	ARD	MAE	δ_1	δ_2	δ_3	RMSE	ARD	MAE	δ_1	δ_2	δ_3
Gated2Depth [3]	Mono-Gated	D	16.15	0.17	8.07	75.70	92.74	96.47	28.68	0.22	14.76	66.68	82.76	87.96
Gated2Gated [9]	Mono-Gated	MG	14.08	0.19	7.95	79.84	92.95	96.59	16.87	0.21	9.51	73.93	92.15	96.10
Sparse2Dense [7]	Mono-Sparse	D	9.97	0.11	5.22	87.06	95.77	98.20	10.05	0.11	4.77	88.06	96.57	98.63
KBNet [10]	Mono-Sparse	D	13.77	0.16	8.73	80.98	**99.33**	**99.67**	15.27	0.17	9.54	78.54	**99.31**	**99.63**
PackNet [4]	Mono-RGB	M	17.82	0.20	10.21	66.35	87.85	95.61	17.69	0.21	9.77	72.12	90.65	96.51
DepthFormer [5]	Mono-RGB	D	12.15	0.11	6.20	85.18	95.76	98.47	10.59	0.09	5.06	90.65	97.46	99.02
ACVNet [11]	Stereo-RGB	D	11.70	0.08	5.25	89.91	96.33	98.47	9.40	0.07	4.08	94.61	98.36	99.12
RAFT-Stereo [6]	Stereo-RGB	D	10.89	0.09	5.10	90.47	96.71	98.64	9.40	0.07	4.07	93.76	98.15	99.09
GatedStereo	Stereo-Gated	DGS	**6.39**	**0.05**	**2.25**	**96.40**	98.44	99.24	**7.11**	**0.05**	**2.25**	**96.87**	98.46	99.11

- Improvement of 50% MAE compared to next best RGB stereo method
- Improvement of 74% MAE compared to next best monocular gated method

→ see paper

Gated Stereo:
Joint Depth Estimation from Gated and Wide-Baseline Active Stereo Cues



algolux

Mercedes-Benz

PRINCETON UNIVERSITY

Data and code are available at
https://light.princeton.edu/publication/gatedstereo